Progress in IS

Yesha Sivan *Editor*

# Handbook on 3D3C Platforms

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

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

# Foreword: Let's Design a Place to Impact the World

**Anshe Chung**


It was a bit over 10 years ago, on March 26th of 2004, when I created my first avatar in Second Life. I was curious about the promise of a 3D world, built by its users, with an online society not subjected to the usual censorship. Of course, I had no idea what journey this would take me to.

I still remember how small and experimental the place felt with a village-size community of smart and friendly people, and how surprised I was when I learned that many of the users were seriously living a whole online life there, calling themselves "residents" instead of "users" or "players." After a certain time, I felt a sense of realism and suspension of disbelief—a feel I had never felt before online. This feel was entirely based on the depth of social interaction and interactivity with the 3D environment, not realism of visuals or user interface.

Two years later, in May 2006, my avatar appeared on the cover of the Businessweek as virtual world land baron, and shortly after, news spread that I made my first million in a virtual world, a novelty at the time.

Anshe Chung Limited, the firm that I created with Guntram Graef, became a major player in the emerging field of virtual worlds and continues to serve many clients, particularly in the areas of virtual world real estate and finance. We were not entrepreneurs discovering virtual worlds but we were virtual world users learning, within a virtual world, how to become entrepreneurs.

The various chapters of this book demonstrate the opportunities, dangers, and complexities of virtual worlds.

I personally consider the first wave of 3D virtual worlds with user-created content that we have seen in the past 10 years more a proof of concept, a kind of prototype of what the future holds for us. With hardware interfaces maturing and mainstream Internet companies moving into the space with billion dollar budgets, we might soon see things moving to an entirely new level. Facebook, for example, may soon evolve from a social network that already possesses many properties of a virtual world into a fully immersed 3D virtual world experience.

Virtual currencies such as Bitcoin, effectively a decentralized version of the Linden Dollar, are another example of how particular aspects or features, limited to a single virtual world in the past, are now effecting a much larger space such as the Internet or the economy in general. This also reminds us again that virtual worlds do not exist as entirely isolated entities, but that they are also linked to the real world through people, ideas, values, and in many other ways.

Perhaps the most import thing that I have learned from virtual worlds is the fact that virtual worlds serve as a place to learn about and then impact upon the real world, to acquire real skills, and to better understand real people.

I hope that the chapters of this book will help us to enhance our understanding of both the virtual and the real worlds. We are definitely on an exciting journey now, no matter if we tend to spend more time in the virtual or the real: Both are connected.

# Preface: 3D3C Platforms: Let's Shape the Future

**Yesha Sivan**

*Dr. Grace Augustine: Is the avatar safe?*
*Jake Sully: Yeah it's safe. You are not gonna believe where I am!*
*From the movie Avatar*

## The 3D3C Factors: The Case of Facebook Paying US$2bn for Oculus Rift

In March 2014, Facebook snapped up Oculus Rift at the US$2 billion price tag. What led a software-only firm to assign such value to a hardware firm that serves as a gateway to the 3D universe?

Let us look at the history of the Rift. Following a demonstration of the Oculus Rift prototype at E3 game show in June 2012, on August 1, 2012, the company announced a Kickstarter campaign for the product. Within 4 hours, Oculus secured its intended amount of US$250,000, and in less than 36 hours, the campaign had surpassed US$1 million in funding, eventually ending with US$2,437,429.

About 12 months later, on June 19, 2013, Oculus Rift announced a US$16 million Series A funding. The round was co-led by Spark Capital and Matrix Partners. After about 6 more months, on December 12, 2013, the firm announced a $75 million Series B funding, led by Marc Andreessen who joined the company's board on behalf of his VC firm Andreessen Horowitz. In March 2014, Facebook snapped up Oculus Rift at the US$2 billion price tag. Why?

My answer: Facebook needed the 3D factor to complete its 3D3C strategy. Facebook has the Community factor (in the form of almost a billion users), the Creation factor (albeit in a very limited sense, by allowing its community to post, add videos, share, etc.), and the Commerce factor. The first factor of any 3D3C strategy was missing and Facebook was eager to have it. Oculus Rift gave Facebook the opportunity to own a key to the ultimate 3D3C platform. In essence, they own the mouse for windows—the gateway to a new operating system of the twenty-first century.

The claim of this book is simple: we are entering an age where these four factors (3D, Community, Creation, and Commerce) join forces to create a new era of sharing, communicating, shaping, shopping, learning, dancing, traveling, etc.—a new era of being.

## Motivation: Preparing for a Long-Term Paradigm Shift

Around 1990, a disruptive technology—the Internet—emerged. New businesses, like eBay, Amazon, and Google that embraced the Internet in innovative ways, thrived, while companies like Tower Records, Barnes & Noble, and Rand McNally, which failed to embrace the Internet early, were less fortunate. (Tower folded, Barnes & Noble missed the online business that now belongs to Amazon, and Rand McNally failed to capture the online mapping business.)

Circa 2008, another disruptive technology—smartphones—emerged. A new generation of mobile phones, led by the iPhone and Android brands, is changing the communication and application markets. Apple, the leader of the field, and Motorola, leader in embracing the Android operating system, are winning—Nokia and Microsoft are losing. Thousands of application developers are harnessing the value of the new market of smartphones.

Every 10–20 years, we witness a technology shift, comparable in magnitude to that of the Internet or smartphones. Such paradigmatic shifts can break older firms, reshape entire industries, and create enormous value and wealth. Missing such a shift, however, could be detrimental to businesses and IT suppliers alike: the shift from mainframe computers to mini-computers (which IBM missed and Digital captured); from mini-computers to PCs (which Digital missed and Compaq captured); and from PCs to the network computer (which Microsoft missed and Google captured).

I claim that 3D3C platforms will—in due course—offer such a paradigm shift. What we see now with google Glass and Oculus rift (2014) is just a beginning. In comparison to the Internet age, we are at the "Gopher" stage (Gopher was a pre-browser method to view hyperlinked materials).

The timing of full impact of 3D3C platforms in not yet set. We observed a spike of interest in 2006/2007. The years 2008–2009 were more social in nature with Facebook-like technologies catching our attention. The years 2009–2010 seem to be more mobile in nature with smartphone technologies at the center of the public's focus. The following years, the growth of 3D TVs and the emergence of phone-based augmented reality seem to re-push the field of virtual reality. In any event, time is ripe for research to explore the field and suggest policies, technologies, and applications that will make use of the field, and/or advance it.

## About This book

This book is connected with the Lantern issue (Parts 1 and 2) published by the Journal of Virtual Worlds Research (JVWR) in 2014, where we shed light on some aspects of the vast, interconnected, and expanding field we call "virtual worlds."
**The first part of the book focuses on tools of virtual worlds:**

- A Comparison of Bots in Social Networks and MMOGs
- US Taxation of Virtual World Economies: An Empirical Review
- Fostering Team Creativity in Virtual Worlds
- Virtual Currencies, Micropayments and Fiat Money: Where Are We Coming From and Where Does the Industry Stand?
- Privacy, Law, and Virtual Worlds
- Avatars and Behavioral Experiments: Methods for Controlled Quantitative Social Behavioral Research in Virtual Worlds
- Research Methods in Desktop Virtual World Environments: Framing the Past to Provide Future Direction
- Multilingual issues in Virtual Worlds: A General Review

**The second part of the book focuses on applications of the virtual worlds:**

- The Virtual Experience Economy: A Service-Dominant Logic Perspective for Metaverse Retailing
- Virtual Psychology: An Overview of Theory, Research, and Future Possibilities
- Virtual Worlds for Energy: A Topical Review
- Past and Present in the Metaverse: A Survey of the Evolution of Historical Virtual Worlds
- Over-view: Virtual Reality in Medicine
- An Exploratory Research Agenda for 3-D Virtual Worlds as Collaborative Learning Ecosystems: Extracting Evidences from Literature
- 1993–2013: A Survey of Two Decades of Artistic Works Using Computational Ecosystems
- Finding Virtual Support: An Exploration of the Evolution and Efficacy of Healthcare Support Groups from the Physical to the Virtual World
- Virtual Fashion as an Industry: Making the World Look Better One Avatar at a Time

The introduction of the book focuses on one showcase: the Metaverse Island.

The purpose of this part is to present one perspective to a 3D3C platform: to give the reader who is less familiar with virtual worlds a sense of the diverse dimensions of one particular 3D3C implementation.

## 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

## Part II Applications

# 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.

**Pekka Alahuhta** is a researcher and Ph.D. student in the Department of Industrial Engineering and Management at Aalto University School of Science, Finland. His research interests are directed to computer-mediated communication and practices that support distributed teams' creative activities.

**Rui Filipe Antunes** has recently completed a Ph.D. in generative animation at Goldsmiths, University of London, with sponsorship by Fundação para a Ciência e Tecnologia in Portugal.

His work has been awarded twice in VIDA, the international competition of art and artificial intelligence (12th and 13th editions), and features in publications such as Preble's Artforms and Leonardo. A large number of curatorial projects and shows have featured his work, including the International Festival of Digital Art at Waterman's, the A-Eye exhibition celebrating the 50 years anniversary of the AISB, and a solo show at the Tin Shed gallery in London, UK. In 2009, his work featured in the exhibition Lá Fora at Museu da Electricidade, in Lisbon, Portugal, a perspective of historical and contemporary art by Portuguese living abroad.

**Dennis Beck** is an Assistant Professor of Educational Technology at the University of Arkansas. He enjoys teaching courses in instructional design, integrating technology into the curriculum, and educational technology research. He also has a wealth of experience in the design of online and blended courses in educational and corporate training environments.

He has researched and written about K-12 virtual schooling for special education students and virtual school leaders, as well as the influence of avatar-based simulations and games on stigma experienced by students and teachers. Of special interest is his exploration of the influence of avatar-based simulations on stigma experienced by teachers and students. He is currently working on a study exploring the influence of teacher avatars on student evaluations. He has published in several other venues, including Computers & Education, American Journal of Distance Education, Educational Administration Quarterly, Journal of Educational Research, and the Journal of Virtual Worlds Research.

**Lotfi Bellalem** is a certified teacher at the University of Lorraine. He has got a Ph.D. in Computer Sciences at the University of Metz in 1998. He integrated the team TALARIS (now Synalp) at the Loria (UMR 7503-CNRS—University of Lorraine-INRIA) in 2005. In this framework, he participated in the ITEA2 Metaverse1 project and focused his attention especially on the multilingual exchanges based on text in virtual worlds. Currently, he works on emotion detection from text in the context of the Empathic project (ITEA3 11005).

**Nadia Bellalem** is an assistant professor at the University of Lorraine. She has got a Ph.D. in Computer Sciences at University Henri Poincaré in 1995. She is a member of the team "Synalp" at the Loria (UMR 7503-CNRS—University of Lorraine-INRIA). The domain of her research concerns essentially the man–machine interaction. Indeed, she was interested in multimodal human–machine dialogue including gesture and speech and, then, in multilingual aspects of the man–machine communication. In this context, she participated in the ITEA2 Metaverse1 project (Setting global standards among real and virtual worlds). She is now investing on the topic of the emotion detection from text in the ITEA3 Emphatics project (ITEA3 11005, Enabling intention and emotion aware products).

**Ruy Valdes Benavides** graduated from the Department of Economics and Finance at the Universidad de Guanajuato, Mexico, in May 2013. Ruy does research on monetary and payments systems DSGE models, with an emphasis on the introduction of virtual currencies and its interaction with monetary policy. His focus is on the analysis of the implementation of modern financial payment systems as a potential tool for improving development. He has worked as a private consultant and as a lecturer of economics in Universidad de la Salle, Mexico. Together with Paula Hernandez-Verme, his thesis advisor, he has presented this research about virtual currencies in several international conferences from the Americas to Europe. Ruy was co-coordinator of Amnesty International Guanajuato and has published on the potential benefits of technology in Human Rights. Ruy is currently doing an M.A. in Development Studies with a major in Economics of Development in the International Institute of Social Studies at Erasmus University Rotterdam.

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**Samuel Cruz-Lara** got a Master's Degree in Computer Science in 1984 (University Henri Poincaré, Nancy 1) and a Ph.D. Degree in Computer Science in 1988 (National Polytechnic Institute of Lorraine). The central topic of his Ph.D. thesis was the generation of integrated development environments by using attribute grammars. He is currently an Associate Professor at the University of Lorraine and Deputy Director of the Nancy-Charlemagne Institute of Technology. He is also a permanent researcher at LORIA (UMR 7503) a computer research center common to CNRS, INRIA, and the University of Lorraine. He belongs to the SYNALP team (Statistical and sYmbolic NAtural Language Processing) and has conducted several research activities oriented essentially toward the association of linguistic and multilingual issues to multimedia, virtual worlds, and serious games.

He has participated in several projects, in particular ITEA2's METAVERSE1 (ITEA2 07016) and SEMbySEM (ITEA2 07021) projects. Currently, within ISO's TC37/SC4 "Linguistic

Resources Management," he is the project leader of MLIF (Multi Lingual Information Framework), a high-level ISO-based abstract model for dealing with multilingual textual content [ISO 24616:2012]. Samuel Cruz-Lara was also a member of the former SYnchronized MultiMedia (SYMM) Group of the World Wide Web Consortium and he was coeditor of the SMIL 3.0 specification (Synchronized Multimedia Integration Language). He is currently a project leader, at LORIA, of ITEA3's EMPATHIC PRODUCTS project (ITEA3 11005). Within this project, he's focusing on Sentiment Analysis and Emotion Detection on Multilingual Textual Information.

**Donna Davis** is the Director of the Strategic Communication Master's program at the University of Oregon's George S. Turnbull Center in Portland, Oregon. After a 25-year career in strategic communication with special interest in nonprofit advocacy work, she earned her Ph.D. at the University of Florida. Her research has focused on virtual identity and the role it plays in the development of community and relationships in virtual environments and other emerging social media. Her current research focuses on digital social capital formed and subsequent improved quality of life measures among people with Parkinson's disease and disability communities in the 3D virtual world. In these environments, individuals are able to represent themselves as they choose and function regardless of ability or disability. She was an inaugural faculty fellow for the University of Oregon School of Journalism and Communication Center for Journalism Innovation and Civic Engagement.

**Alexandre Denis** studied computer science at the French Parisian engineering school ESIEA. His internship on multimodal dialogue systems, performed at the LORIA in Nancy in the Langue et Dialogue team (now Synalp), enticed him to research and he continued with a computer science M.Sc. on reference models. He then did his Ph.D. with Matthieu Quignard under the supervision of Laurent Romary about the grounding process in dialogue systems. He then pursued his research still in the same team working on online communities of practice (CCCP-Prosodie project), instruction generation in situated interaction (GIVE project), and language learning in virtual worlds (Allegro project). He is now researching emotion detection from text and computational models of emotions in video games at the University of Lorraine in the Empathic Products European project (ITEA3 11005).

**Nick V. Flor** is an Associate Professor in the Marketing, Information Systems, and Decision Sciences group at the University of New Mexico's (UNM) Anderson School of Management. He holds a Ph.D. and Master's in Cognitive Science and a Bachelor's in Computer Science, all from the University of California, San Diego. Prior to UNM, he spent 8 years as a faculty member at Carnegie Mellon University's Graduate School of Industrial Administration. Before academia, he worked in industry for 10 years as a software engineer and project leader at Hewlett Packard's San Diego Division. He has published extensively in the areas of virtual communities and online social systems. His current research interests lie in the application of 3D virtual worlds to renewable and sustainable energy education, where he is co-PI on the National Science Foundation's SEPTET grant. He is the author of Web Business Engineering and a past Director of UNM's Interdisciplinary Film & Digital Media Program.

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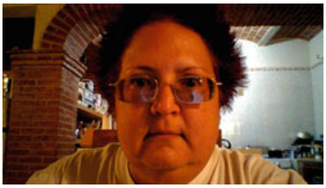
**Robert Goldstone** is Chancellor's Professor in the Psychological and Brain Sciences department and Cognitive Science program at Indiana University, where he has been a faculty member since 1991. His research interests include concept learning and representation, perceptual learning, educational applications of cognitive science, decision making, collective behavior, and computational modeling of human cognition. He was awarded two American Psychological Association (APA) Young Investigator awards in 1995 for articles appearing in Journal of Experimental Psychology, the 1996 Chase Memorial Award for Outstanding Young Researcher in Cognitive Science, a 1997 James McKeen Cattell Sabbatical Award, the 2000 APA Distinguished Scientific Award for Early Career Contribution to Psychology in the area of Cognition and Human Learning, and a 2004 Troland research award from the National Academy of Sciences. He was the executive editor of Cognitive Science from 2001 to 2005, associate editor of Psychonomic Bulletin & Review from 1998 to 2000, and associate editor of Cognitive Psychology and Topics in Cognitive Science from 2007 to 2014.



**Paula Hernandez-Verme** does research in the fields of Macroeconomic and Monetary theory, Open Economy Macroeconomics, Dynamic Systems, Payments Systems, Monetary History, Econometrics, and Quantitative methods. Paula was born in Lima, Peru, and studied Economics at the Pontificia Universidad Catolica del Peru (PUCP), where she obtained the degree of Licentiate in Economics in December of 1994. Between 1994 and 1996, she worked as Associated Faculty of Economics in the same university. Paula also worked for a private consulting company in Peru between 1994 and 1997, as Senior Analyst in charge of Macroeconomic Analysis, Quantitative Methods, and the Consumer Price Index. She obtained a Master of Arts and a Ph.D. in Economics from The University of Texas at Austin. While at this school, she received several awards and fellowships, such as The University Continuing Fellowship, and had the great pleasure of working under the guidance of Bruce D. Smith and Scott Freeman. She was an Assistant Professor of Economics at Texas A&M University between August 2002 and May 2009. Since July 2009, Dr. Hernandez-Verme has worked as a Full Professor at the Department of Economics and Finance at the Universidad de Guanajuato, in Mexico.

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**Kathy Keeling** is currently an associate professor in Research Methods and Data Analysis at Manchester Business School. With a Ph.D. investigating and modeling user acceptance of e-banking services, M.Sc. Applied Psychology, and B.Sc. Psychology, she researches cross-disciplinary areas and applies psychological models of behavior with particular interests in retailing, e-tailing, and technologically mediated services. Relevant journals she has published in are *Journal of Retailing, Journal of Business Research, International Journal of e-Commerce, and Journal of Marketing Management*.

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**William Latham** is a pioneer of digital art and is well known for his evolutionary computer art at IBM Research from 1987 to 1993. His work was widely shown in internal touring exhibitions to Japan, Australia, and Germany sponsored by the British Council. He was then Creative Director of leading UK Games Development Studio Computer Artworks Ltd for 10 years, creating computer games published by Universal Studios, Warner Interactive, and Microsoft. William was then MD of consultancy company Games Audit Ltd whose clients included IFG (part of Allianz Insurance) and Malta Enterprise. At Goldsmiths since 2007, his research projects include an Innovate UK award into procedural architecture. He is a colead with Prof Fol Leymarie on an exciting serious games research project into protein docking with Imperial College Bioinformatics Department funded by the BBSRC. His recent Mutator 1 + 2 Exhibition sponsored by Arts Council England was shown in Brighton and Brussels and is on show in Dundee. He is industrial liaison lead for the IGGI Ph.D. Research Program and is codirector of SoftV Ltd working on games for Neuroscience/health with UCL.

**Nicola Lercari** is an Assistant Professor of World Heritage at the University of California Merced where he investigates digital methods of heritage preservation, visualization technologies for public history, and the usage of cross-media systems in museums. Dr. Lercari received his Ph.D. in History and Computing from the University of Bologna, Italy, in 2011 with a dissertation on the visualization of medieval urban spaces in XIII century Bologna (*Nu.M.E.* project). Nicola has worked on several digital humanities initiatives both in Italy—CINECA supercomputing center and the University of Bologna—and in the United States: at Duke University, Nicola led the development of *Venice Virtual World*, a narrative-interactive virtual world representing life and cultures in early-modern Venice; at the University of California Merced, Nicola is a founding faculty member of the World Heritage program and he contributed to the development of the serious game for heritage *Fort Ross Virtual Warehouse*. Dr. Lercari's scholarship explores the analytical role of visualization in the interpretation of the past and its material culture. Specifically, he strives to develop a theoretical framework able to explain the power and cultural value of virtual worlds and serious games in conveying new information about our past, heritage, and societies.

**Frederic Fol Leymarie** joined the Computing Department at Goldsmiths in mid-2004. He first initiated and directed the M.Sc. Computational Arts and then got William (Latham) to join him at Goldsmiths and initiate the M.Sc. Computer Games and Entertainment (launched in 2008), the first (and leading) industry facing M.Sc. for games programming in the Greater London area (www.gamesgoldsmiths.com).

Frederic is currently co-PI of the BBSRC-funded DockIt gamification research project focused on the fundamental problem of protein docking (how to bring complex 3D protein molecules together in ways that make biological sense). This work is in collaboration with Prof. Latham and Prof. Mike Sternberg at Imperial College. Frederic is also working on modeling the human visual perception of shapes (2D, 3D in movement).

Frederic is a graduate of Brown University, Engineering Division (Ph.D., 2003), McGill University, Centre for Intelligent Machines (M. Engin. 1990), and Ecole Polytechnique of Montreal, Electrical and Aeronautics Engineering (1986). In the 1990s, he spent time between Canada (CIM at McGill) and France (at the School of Mines of Paris and in industry working in the area of 3D Geographical Information Systems). For more details on Frederic, including recent publications, see www.folleymarie.com.

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**John T. Overocker** (J.D., University of Baltimore) is an Attorney working in Private Practice in Carrollton, GA. He practices in both civil and criminal defense cases. He has worked on the appellate level on the grounds of the Fourth Amendment.

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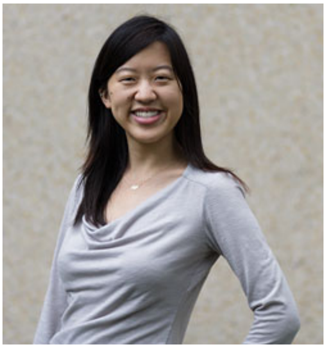

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# Introduction to 3D3C

**Yesha Sivan**

## 1 A Formal Definition: 3D + Community, Creation and Commerce

Let's formally define 3D3C platforms as an aggregate of four factors: a **3Dimentional World**, **Community**, **Creation** and **Commerce**. (For an older review of 3D3C see Sivan, 2008). I use Second Life the most advanced system to clarify the factors.

**3D World**: A dynamic world where viewers see objects like avatars, houses, and cars. The world has land, a sky, a sun (or maybe more than one sun), wind, gravity, water and fire. Avatars move around freely. The user can further examine the world from different points of view (roaming camera). An expanded version of 3D includes various inputs (sensors like Microsoft Kinect) and outputs (Rift, Google Glass) and even 3D Printers (now starting to be priced under US$1000 range).

**Community:** Humans are social animals. Unfortunately, during the past century we gradually distanced ourselves from socializing—mainly through the advent of television. We sat alone in front of the screen, watching passively and without much interaction. We did not react, we did not create and we could not see how others felt or reacted. The Web actually enhanced this feeling of "isolation" (in a manner of speaking). Then emails emerged, followed by the "chat," the cellular phone, SMS—and multi-player worlds. So we are now actually returning to the community, to friends, to people. Amazon began this trend by allowing readers to review and recommend books. Later, companies like YouTube allowed users to upload

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video contents. Moreover, of course, we have blogs (which include comments), social sites such as Facebook (or the old MySpace).

**Creation**: Second Life's (SL) greatest invention and technological achievement was in giving users the capability to develop their own "things" (or in SL jargon: objects). In fact, users created the entire content of SL (barring a few sample and demo objects). Objects creation can be done at several levels—first, by moving pre-constructed objects from one place to another (e.g., rearranging furniture in a home, or setting up a nightclub). Second, an object (e.g., a house) may be assembled from basic components such as walls and ceilings, followed by "painting" them with various textures. These basic components, called primitives, allow the construction of complex objects at a very high level of precision (see the SL example of Susan Vega's guitar, (infinitemind, 2006a & 2006b) which is made of more than a hundred primitives). Linden hit the nail on the head when they built a programming language (LSL—Linden Script Language) into the world. LSL allows users with programming abilities to endow their objects with behavioral attributes. As a result, we can see fish swimming in schools, a game of golf, pistols that shoot, and even dancing. Largely, these are expansions of the capabilities found in worlds such as Sims, combined with industrial CAD software packages.

**Commerce**: Linden, maker of SL, has created an internal currency—the Linden Dollar (or L$, for short). There is a defined exchange rate between the Linden Dollar and the US Dollar—in the last years one US$ was worth about L$265. The entire economy of the SL world is based on this currency. The credibility of this economy is built on two levels—one conceptual and the other technical. At the conceptual level Linden established and operates its own exchange. Within it, Linden guarantees the exchanging of L$ to US$ immediately and at any time. For instance, if a user earned L$2600 from tips, she could access the Linden website and exchange them for about US$10, which would be immediately transferred to her real bank account. Going the other way, if the user needed L$6,000 for a new hairdo, she could immediately buy them for about US$20. At the technical level, Linden has currency and commerce integrated into the world, i.e. every object can have purchase-ability and a price.

Ultimately, the value of such worlds stems from the **integration** of the **3D**, **Community**, **Creation** and **Commerce**. Second Life reveals the emergence of this integration. In SL you will find a price for objects, permissions (e.g., an object may be restricted from being sold), and ownerships. The commerce is structured into the world itself. For example, let us assume that we enjoyed Pepe's dancing (and her Spanish accent) and wish to tip her. We point to her and transfer money to her by clicking a button. If Pepe wants to buy a new blouse, she goes to the shop, points to the blouse of her choice and buys it for L$2000. The blouse is defined as a unique object in this world, and Pepe will not be able to copy it. The shopkeeper will receive L$500 for the blouse, and the blouse manufacturer will receive L$1,500 (in accordance with a previously defined business agreement between them). At the end of the month, the shopkeeper will pay rent to the landowners, also based on a predetermined agreement.

**Table 1** Different worlds viewed via the 3D3C prism

| Sample Platform | 3D | Community | Creation | Commerce |
|---|---|---|---|---|
| ActiveWorlds | *** | * | *** | (per case) |
| Club Penguin | * | * | * | * |
| Google Earth | *** | *? | *** (SketchUp) | ? |
| IMVU | *** | *** | ** | *** |
| Second Life | *** | ***** | ***** | ***** |
| WOW | ***** | *** | * | * |

Key: * = Very Low ** = Low *** = Moderate **** = High ***** = Very high

This integration of 3D abilities, organized and managed Communities, immediate Creation capabilities of objects and services, and a virtual Commerce, which actually becomes real—is the allure of 3D3C platforms in general.

We use the word "platform" as a way to include worlds, systems, tools, and environments—platforms also hint at their technical nature of the 3D3C factors—platforms enable applications. Historically we used also 3D3C systems and 3D3C worlds. These terms are interchangeable.

**Typical Platforms via the 3D3C Prism**

Next, using the 3D3C framework, let us examine typical platforms that represent a spectrum of platforms; they were selected to highlight various aspects of the 3D3C definition and not because of their impact on the field (Table 1). (An earlier version of this table was first presented in Metanomics, a virtual broadcast, hosted by Bloomfield (Ed.), 2007).

- WOW (World of Warcraft) is the most popular multi-user game with more than 10 million users. WOW has relatively good 3D graphics. Since it is centrally created the graphics delivery can be optimized. Creation is relatively limited, (you can select your avatar and dress it, but you cannot change the environment). Real commerce is limited. I noted one star ('*') because while users cannot buy WOW gold for real money in the game, they can buy it on the Internet by paying another player to send them money in-world.
- IMVU is a chat world merged with MySpace-like personal pages (acronym can be read like Instant Message with a View). It does not allow your avatar to walk around, you move from one scene to another. In many ways, it is a limited world compared to WOW or SL. Still, it has 3D (only 3 stars); a strong community infrastructure (with groups, group chat, friends, and people who visited "my page" capacity albeit without permissions), and real money commerce—where you can buy and sell money (To buy and sell IMVU cash see for example: http://imvu.anshechung.com/index.php).
- Club Penguin, purchased by Disney Co. for US$700m in 2007 (Eldon, 2007) is a kids' world. It does not have 3D representation, but rather

(continued)

employs a 2D approach. It has no ability to use currency. Club Penguin (http://www.clubpenguin.com/) is included here to demonstrate that you do not have to be a 3D3C real world in-order to be successful.
- Second Life is a prime example of a full 3D3C world. It now has more than three stars in all the factors. Graphically it is less powerful than WOW, although the addition of reflective water and amazing skies in mid 2008 brought it a step closer to four stars. (Note: new Graphical Processor Units emerge from the likes of Nvidia and AMD-ATI, coupled with better 3D algorithms. We should expect the graphics to improve continuously. The number of stars should be adjusted to the relative market conditions).
- ActiveWorlds ("Home of the 3D Internet since 1995") is a platform for worlds and not a specific world. ActiveWorlds is used to build worlds, so the "rules" of each world are determined by its owner. It supports 3D and some of the features needed for Community, Creation, and Commerce. It is really for every world owner to make a decision how to use the various factors in their worlds (Activeworlds is active since 1998 in this field. See http://web.activeworlds.com/index.php.)
- Google Earth is here because—in theory—it can become a virtual world or an infrastructure to build and run worlds. With SketchUp, Google's simple and free editing tool, one could easily create 3D objects. We are still missing structured community and commerce but third party tools, as well as Google tools like "Open Social" (for community) or Checkout (for commerce) may close that gap. (Google's latest foray into the field was Lively—an avatar based on 3D chat system that looked like IMVU. Lively was subsequently discontinued).

In this initial and cursory analysis, I have outlined some of the intended qualities of the 3D3C factors. The factors are designed to be *comparative* (e.g., how the 3D of WOW is compared to the one of IMVU), *relative* (e.g., IMVU did not have many social features when it started. As it progressed it gained more stars), and *explorative* (e.g., Google SketchUp is an option for creation).

This analysis also reveals some of the limits of the 3D3C factors, as they do not fully uncover the intricate nature of the field. We did not cover physics (the inherent ability of the world to support physics which, for example, means that objects can fall to the floor—yes for SL, no for ActiveWorlds); voice communication/interface; and so much more. The 3D3C definition is designed to be a top level starting point.

## 2 Visions for 3D3C Applications

Let us examine a few examples and study the 3D3C factors in action:

**Virtual Physical Therapy—**John is a 75 year old male who had a stroke 5 years ago. Since then, he has been using his virtual home as a starting point for rehabilitation, fun, creation, and productive work. Initially, John was devastated. He could barely move his left arm and left leg. After 2 weeks of intense physical therapy, he continued his therapeutic regime at home. Using remote sensors and actuators (much like the Wii remote, and the Wii fit system), he was able to exercise his body. When he started visiting a local virtual club, treatment became fun—exercise turned into dancing to Trans music.

What we need: To fulfill this vision we will need Nintendo-Wii-like sensors and actuators. We will also need better interfaces that do not involve a keyboard or a mouse. Something more direct that will be able to capture input directly from our minds would greatly enhance the experience. We will also need recognition of the value embodied within the virtual healthcare community. A key factor is allowing people to think about virtual worlds as a place to be and not as a game.

**Virtual Schools**—A few months later, John met Jane. Together they developed the J&J English School. John and Jane designed an immersive virtual school for English language. Each object in the school can "talk" in English. They designed various student-student and teacher-student experiences. They have three regular classrooms where students can sit and watch their teacher on a video screen. They also have a special testing room for SAT (they had to buy that room). Each student who takes the SAT in the J&J School has to pay them (John, in turn, pays back to the College Board, the owners of SAT). With full tuition, students get their own room that includes various items they have learned about. These rooms are often a place for conversation between students and alums of the school. In fact, there are more than 20 different J&J English schools. They all act the same, but are managed by different schoolmasters from all over the world. John has learned that hiring teachers is a key factor. Each teacher turns the school into his or her own. John and Jane focus on the infrastructure; the teachers focus on the actual teaching. They share the revenues from the students.

What we need: Today, learning is one of the top industries in Second Life. For the first time, educational institutions of all sizes can enjoy a common place of learning and allow synchronized learning. I have personally used SL to teach Executive MBA courses at the Bar Ilan University in Tel Aviv. Students use virtual worlds as a simulation to start small businesses, to work with technology developers and to feel almost real. Note that the commerce factor is critical for the J&J School system. The ability to run a franchise, where the firm maintains quality and standards, and the local managers own the customers, is still missing. Classic ERP firms like SAP, Oracle and others will need to fill this gap.

**Virtual Concerts**—Once every 2–3 months John and Jane enjoy virtual concerts. In February, Live NationVcon hosted Madonna. John had to wait in line for two hours to get the ticket. Of course, "wait" has a different meaning—"experience" is more like it. The line included meeting old friends and viewing clips of previous concerts. The unique thing about Live Nation Vcons is the fact that you get to experience the concerts with your friends. In essence, a Vcon allows up to a 100 people to "assemble" in the same place. The concert lasts eight hours. It starts with a couple of movies, a few earlier shows, and a simple get-together party. The concert itself is streamed to various virtual halls. Each visitor gets to pick one song (as part of the ticket). Together John and Jane have already accumulated 24 Madonna songs. John has traded old Bee Gees songs for some of Madonna's old songs that he missed. His collection is proudly exhibited in his summer home in Vir Italy, Toscana Island.

What we need: This vision seems like the next step for Apple iTunes to take. We are still missing many technologies here. First the ability to have more than 20 people in one place: Today this is a major problem in all worlds. This critical problem is a very difficult one because each attending avatar means that its data need to be streamed to all the other avatars. This causes exponential growth in bandwidth and, with growing attendance, becomes a major computation challenge. While there are some theoretical techniques to solve this (like turning crowds into flat backgrounds and calculating their look and feel once in the server) these are all theoretical solutions. Another set of challenges stems from linking mirror worlds (like virtual Italy) and fantasy worlds (the place with the school resides). Both Google and Microsoft's efforts in this direction are quite impressive.

**Virtual Shopping**—Dan, John's older son, is about to turn 50. It is a good time to buy him a present. John is eager to buy his son something special: A car. John teleports to the nearest Toyota dealership (nearest to his son's residence). While all showrooms are similar, John wants to connect early with the service provider that will maintain the car he intends to buy for Dan. Using the virtual showroom, he builds an initial version of the car. He calls it "Dan's Eagle." He selects the various options. The initial design of "Dan's Eagle" is almost done. John can now view the virtual car. It is delivered to him seconds later. John invites Dan for a preview. Dan is excited; he reviews the design and modifies it a bit. The price changes according to the features he selects. When all is done, Dan approves the order. John and Dan both get a virtual copy of the car. The actual car will take a week to ship.

What we need: The ability to produce a joint design in 3D is already in place. An Israeli company allows you to post your picture on the web and design your own Yogurt cup. However, such efforts are sporadic and tend to be marketing-oriented. We need a full scalable system that involves many aspects—mostly human ones—to allow for this joint car design scenario.

**Virtual Races**—The monthly trip is about to start. John is ready. He has the maps set up, the goals, the targets. John and Dan are ready for the game. Vrace, is a monthly competition that connects Dan (in the real world), and John (in his virtual home). Together they are given quests. They will win if they combine real and virtual knowhow. Dan's Eagle is equipped with four cameras—one for each side. At any given moment, John can see exactly where Dan is. Using his

GPS, John can tell Dan where to go. Jane helps with cracking the clues. She is using 3Dpedia.

What we need: Vrace is a totally new product—a participatory sport that allows people to merge real and virtual worlds. This is not only a game but also an entire culture that will connect people of all ages. Today, most heavy users of Second Life are in for fun. They build, dance, and tour because it pleases them—this is a "Life Style" use of the 3D3C platform.

To conclude: You may have noticed that many of the scenes presented earlier can be done today (2014). In fact, some companies are already doing it. The challenge lies in the *cost of integration*. To accomplish today the above scenes, one would need heavy investments in infrastructure, servers, clients, user training, partner training, etc., all of which will probably turn the effort a theoretical/research only experiment.

However, assuming the infrastructure is already there: the 3D system, the community tools, the creation ability, and the built-in commerce—the cost/value proposition starts to make sense. The key is the integration of 3D, Community, Creation and Commerce—all under the same platform. When we accomplish this standard level of integration—opening up businesses, setting up services, and enjoying the 3D3C platform will be as easy as setting or using a web site or a phone app today.

## 3 MVL Island: An idiosyncratic Showcase to One Kind of a 3D3C Platform

The purpose of this showcase is to present one perspective to 3D3C platform; to give the reader who is less familiar with virtual worlds, a sense to the diverse dimensions of one particular 3D3C implementation.

In 2006, when I looked into virtual worlds, I decided to delve into it not just as an observer but as a creator of content and value. Thus the MVL (Metaverse Labs) Island was born. The initial design was simple—a 256X256m island in Second Life, with a circular road (the grey wooden path seen here) and position various labs around the road.

The initial design of the island was done by Journey McLaglen.

After few years, the MVL island took its own shape which did not change in the last years (from 2010–2014).


**Fig. 1** Aerial view—Island map

The review of the island includes the following parts:

1. Overview
2. Conference Room
3. Students Labs
4. Martial Art House
5. Metavese1 House
6. Tiki House
7. JVWR House
8. Amnon's Ship
9. Nature Forces (Weather & Volcano)
10. The Tree House Office
11. The Fun Cave
12. Lots of Other Things

## *1. Overview*

Just to give a feel of the island from various angles.

**Fig. 2** Aerial view

**Fig. 3** Aerial view

**Fig. 4** Tree house office aerial view

## *2. Conference Room*

The conference room was one of the first buildings created. It was designed as a combination of a reception area, a small meeting room (desk and chairs) and a classroom. It became a storage place for art, and a place for presentations, at a later stage.

**Fig. 5** Conference room

**Fig. 6** Conference room

**Fig. 7** Conference room

**Fig. 8** Conference room—art storage

**Fig. 9** Conference room—desk for chess

**Fig. 10** Conference room from outside

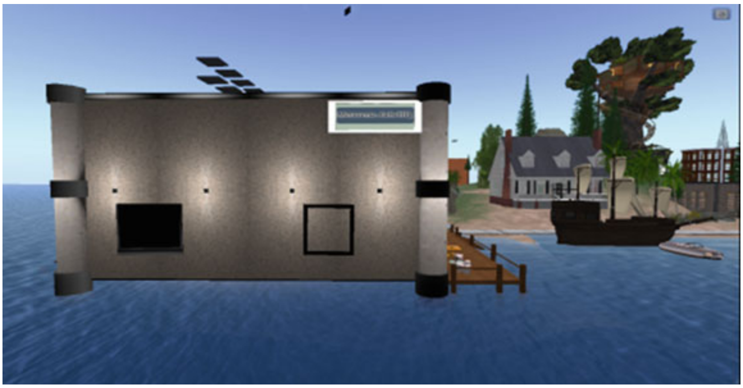

**Fig. 11** MVL conference room from the sea side

**Fig. 12** Slides in the sky—leftovers of slides that were stored in the sky above the conference room

## *3. Students Labs*

The prime use of the island was a place for students to do projects in my "Teaching the Real Using the Virtual" course. The island had about 6 labs in the same structure: area for group projects (final projects), and area of personal test projects.

**Fig. 13** Puppet machine

Fig. 14 Punch—boxed


Fig. 15 Punch open


Fig. 16 Bubble game how to

**Fig. 17** Mess after work

**Fig. 18** View of the personal labs (background with cars on them)

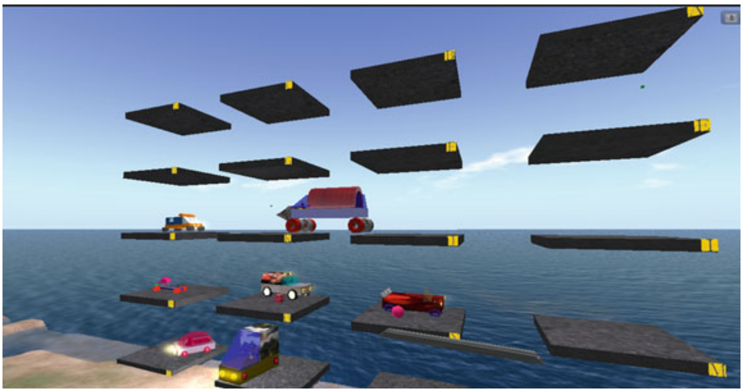

**Fig. 19** Personal work areas with cars

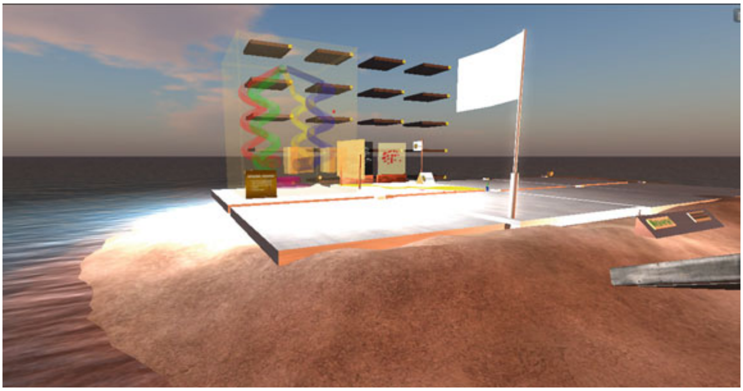

**Fig. 20** Test area for final projects

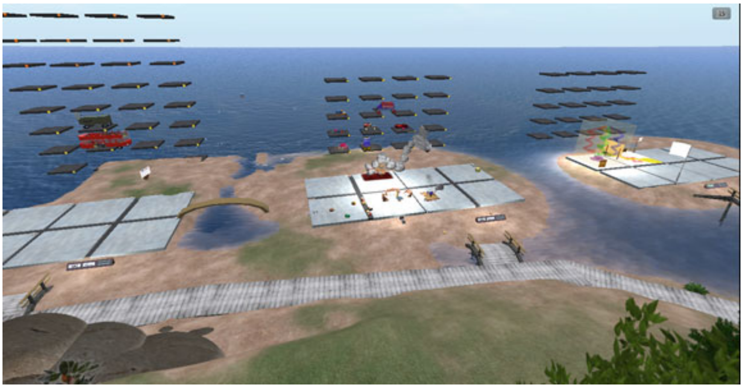

**Fig. 21** Laboratories—Aerial view


**Fig. 22** Class demo day

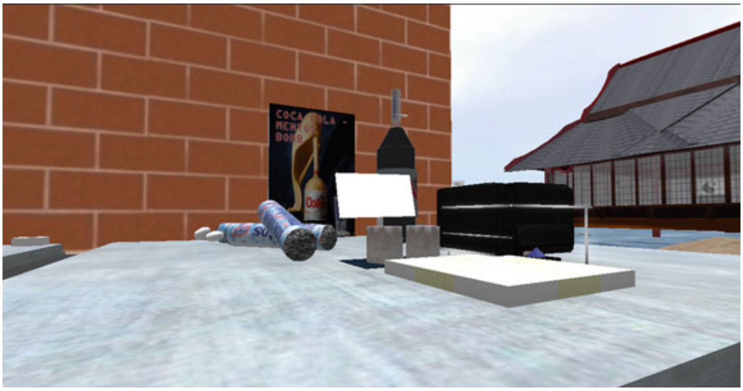

Fig. 23 Lab—coke & mentos

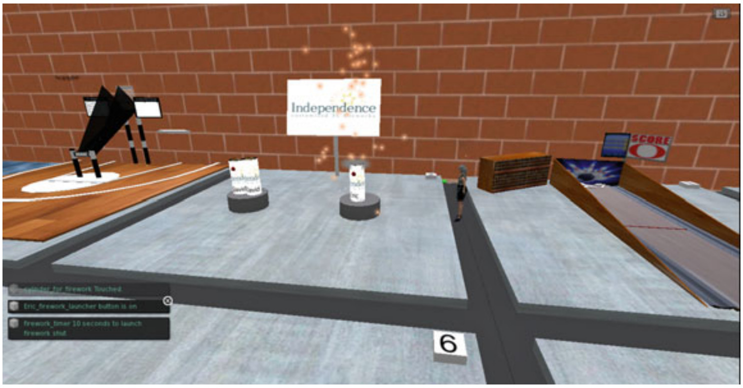


Fig. 24 Lab—fireworks

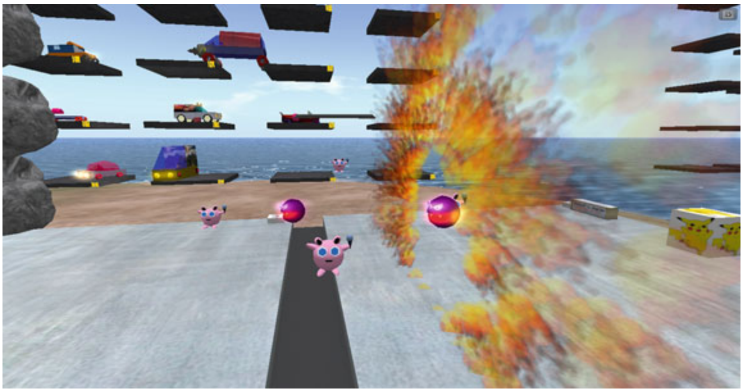

Fig. 25 Firework

## *4. Martial Art House*

One of the first projects was led by Dudasy Clip. The original project allowed an avatar to learn Karate. The project turned to be a business to sell gaming animation.

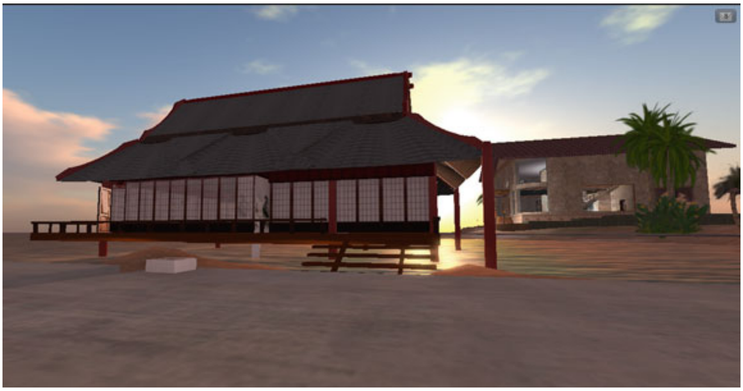

**Fig. 26** Martial arts pavilion—outside


**Fig. 27** Martial arts pavilion

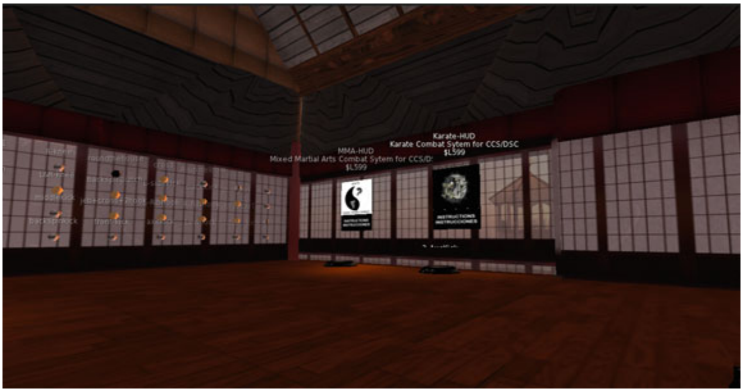


**Fig. 28** Martial arts pavilion—inside

## 5. *Metaverse1 House*

The meraverse1 house was built as the first house for a specific project (www.metaverse1.org).

An especially high-end was chosen.

**Fig. 29** MT1 house

**Fig. 30** MT1 house

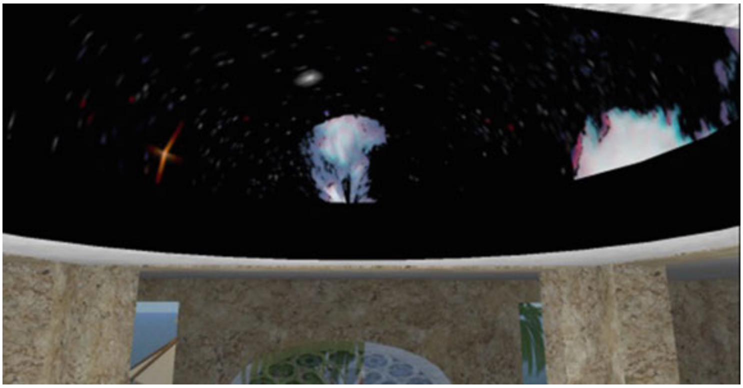

**Fig. 31** MT1 ceiling

**Fig. 32** MT1 ceiling

**Fig. 33** MT1 house

**Fig. 34** MT1 house

**Fig. 35** MT1 house

**Fig. 36** MT1 house

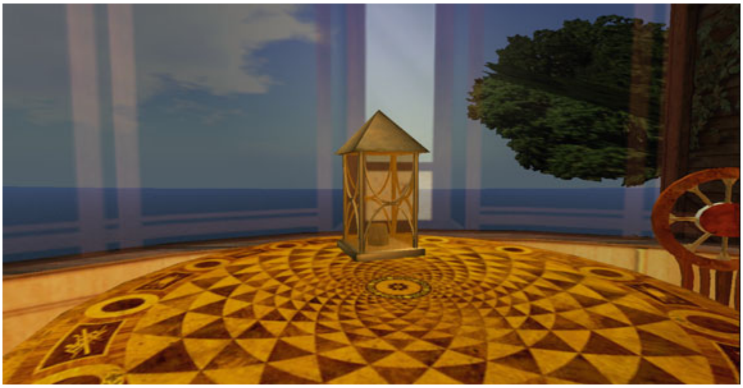

**Fig. 37** MT1 house

**Fig. 38** MT1 house

**Fig. 39** MT1 house

**Fig. 40** MT1 house

**Fig. 41** MT1 house

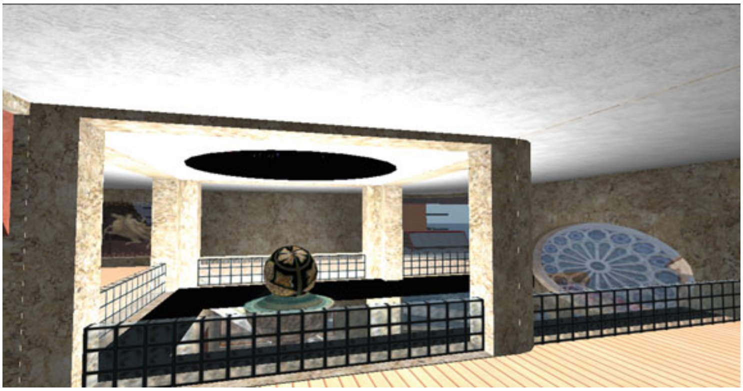

**Fig. 42** MT1 house

**Fig. 43** MT1 house

**Fig. 44** MT1 house

**Fig. 45** Tiki house

**Fig. 46** MT1 house

## *6. Tiki House*

The latest house was developed as a place of vacation. It was owned and updated by Crystal Carbenell who kept it and added their own take to the house.

**Fig. 47** Tiki house

**Fig. 48** Tiki house piano

**Fig. 49** Tiki house bar

**Fig. 50** Tiki house book shelves

**Fig. 51** Tiki house couch

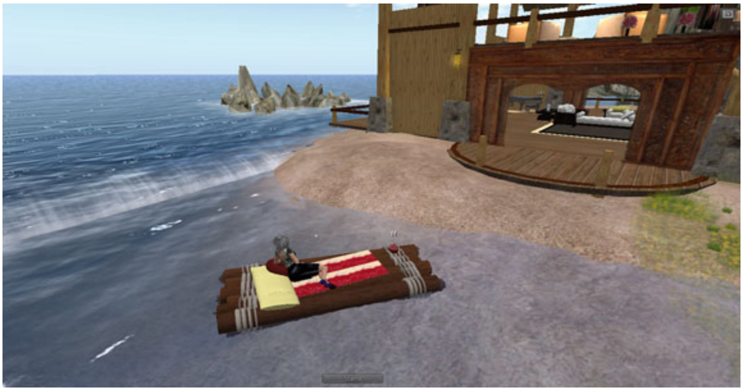

**Fig. 52** Tiki beach

**Fig. 53** Tiki house

## *7. JVWR House*

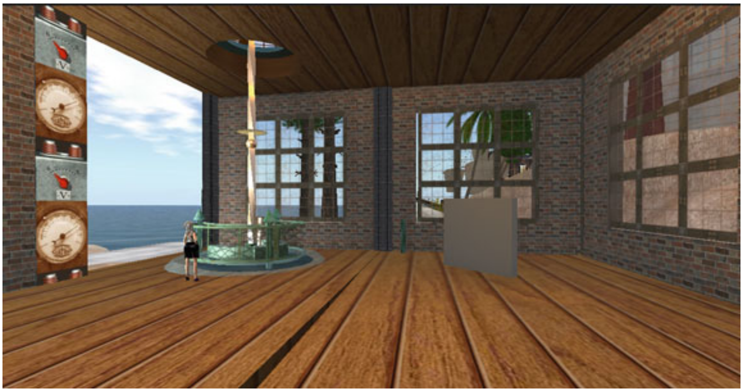

**Fig. 54** JVWR top floor

The journal of virtual Worlds research got its own place, for one of its events.

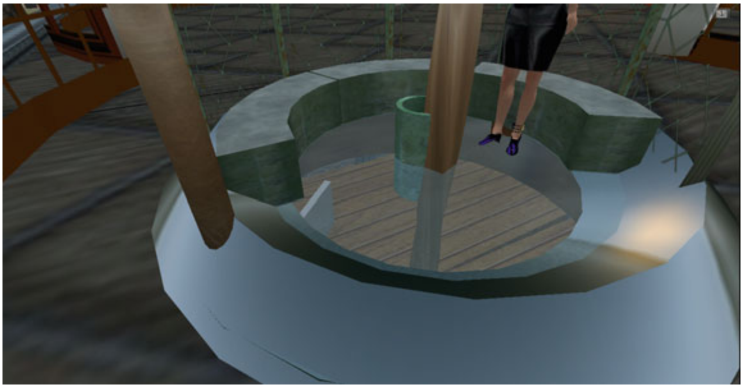

**Fig. 55** JVWR house

**Fig. 56** JVWR house

**Fig. 57** JVWR house

**Fig. 58** JVWR house

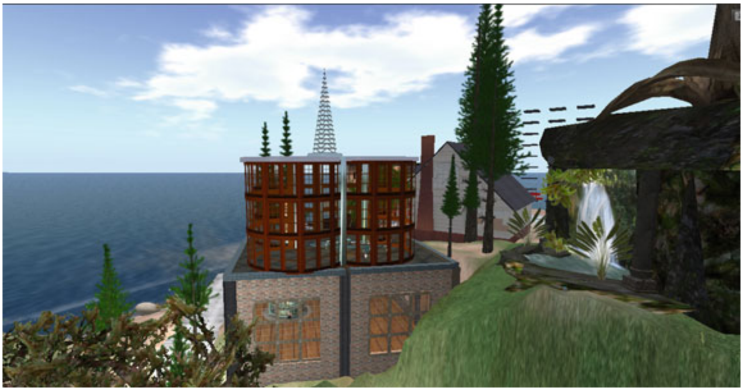

**Fig. 59** JVWR house—top floor

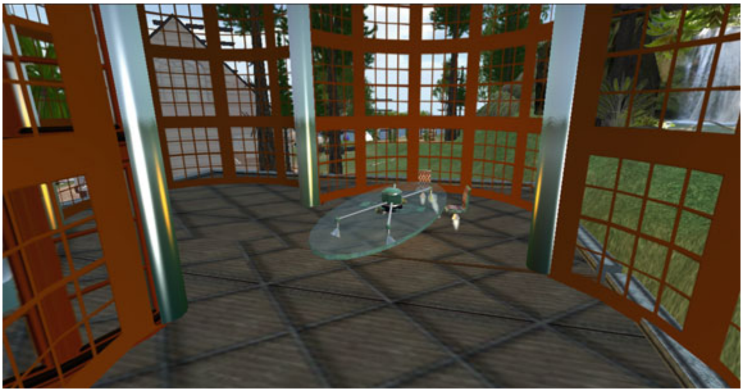

**Fig. 60** JVWR house—top floor

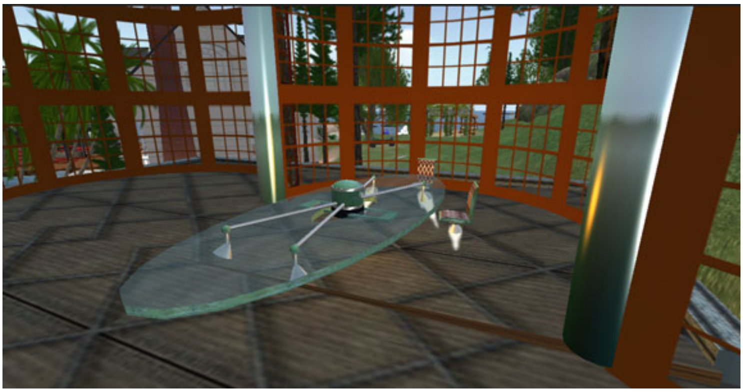

**Fig. 61** JVWR house—top floor

## 8. Amnon's Ship

At some point my son started to create—his major creation: the ship.

**Fig. 62** Ship

**Fig. 63** Ship

**Fig. 64** Ship

**Fig. 65** Ship

## *9. Nature Forces (Weather & Volcano)*

One of the unique creations I got from my friend Ludvaig Lindman: A weather station and a volcano. The weather station allows you to bring rain, snow, etc. The volcano. . . is a volcano.

**Fig. 66** Weather station

**Fig. 67** Weather station

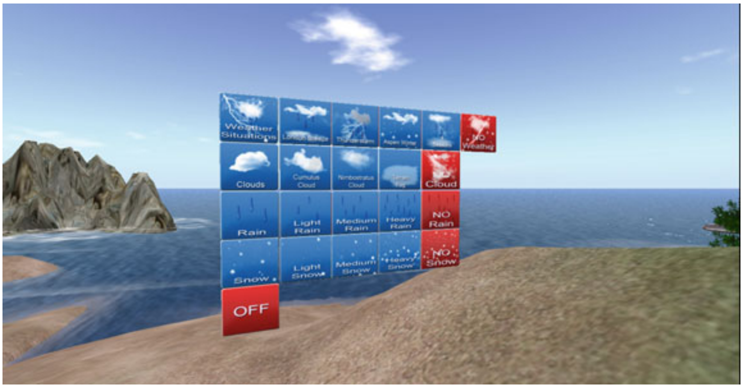


**Fig. 68** Weather machine

**Fig. 69** Relaxing weather bench

**Fig. 70** Volcano—about to explode

**Fig. 71** Volcano—calm

## *10. The Tree House Office*

A full two stories office on a tree house. . . I have always wanted one. . . and I finally got it.

**Fig. 72** Tree house—jukebox

**Fig. 73** Tree house—wedding invitation

**Fig. 74** Tree house—outside


**Fig. 75** Tree house—book shelves

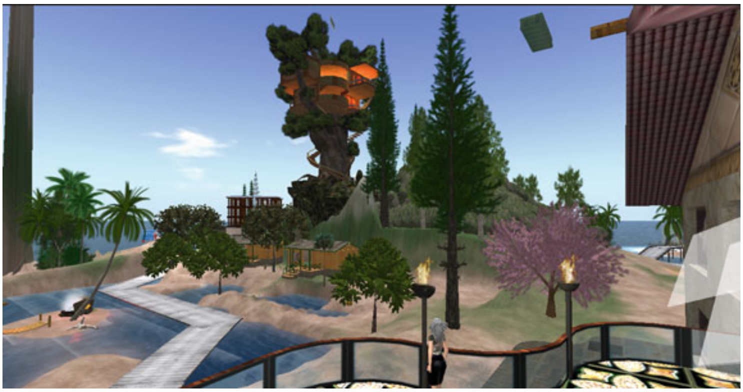

**Fig. 76** Tree house view—from afar

**Fig. 77** Tree house—view

**Fig. 78** Tree house—porch with heating

**Fig. 79** Tree house—my office

**Fig. 80** Tree house—porch


**Fig. 81** Tree house

**Fig. 82** Tree house

**Fig. 83** Tree house

**Fig. 84** Tree house

**Fig. 85** Tree house—living room


**Fig. 86** Tree house—living room

**Fig. 87** Tree house

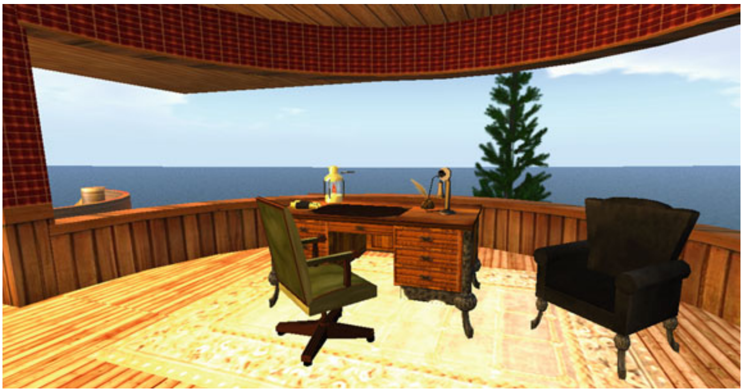

**Fig. 88** Tree house

**Fig. 89** Tree house

**Fig. 90** Tree house

**Fig. 91** Tree house—table

**Fig. 92** Tree house office

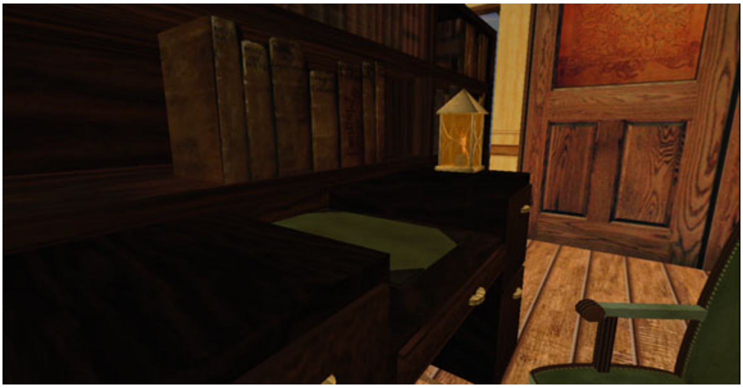

**Fig. 93** Tree house office

**Fig. 94** Tree house office

**Fig. 95** Tree house office

**Fig. 96** Tree house—jukebox

**Fig. 97** Table in tree house with controlled window

## *11. The Fun Cave*

Under the tree house, you need a special cave

**Fig. 98** Secret cave

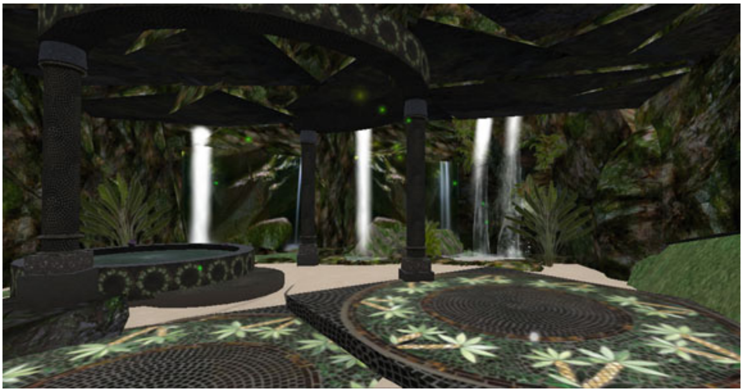

**Fig. 99** Secret cave

**Fig. 100** Secret cave

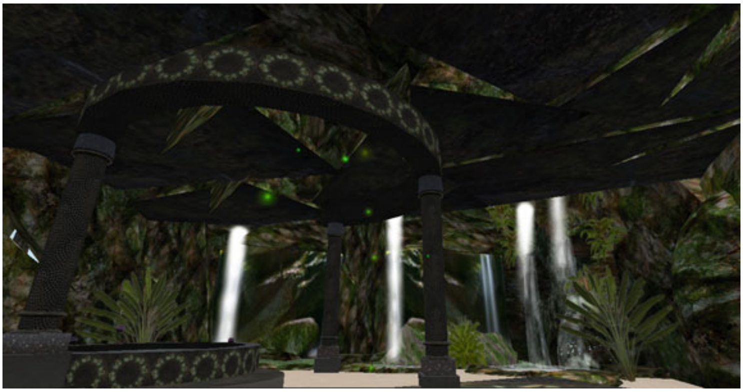

**Fig. 101** Secret cave

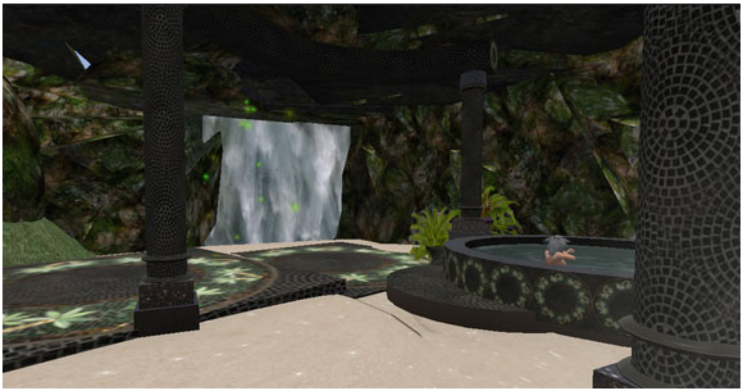

**Fig. 102** Secret cave

**Fig. 103** Secret cave

**Fig. 104** Cave gate at night

## *12. Lots of Other Things*

**Fig. 105** House + bug in ground

**Fig. 106** Bridge

**Fig. 107** Rental houses—never used

**Fig. 108** Water motorcycle—used a lot

Fig. 109 Dance garden

Fig. 110 Relaxing bench


Fig. 111 Relaxing bench

**Fig. 112** Relaxing bench

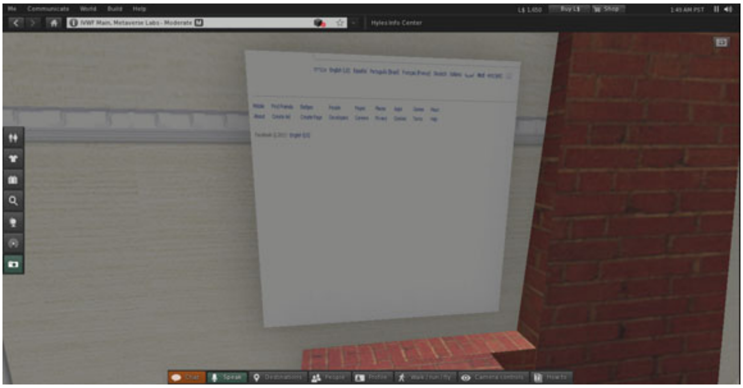

**Fig. 113** URL screen—ability to show web pages inside the world

**Fig. 114** Jacuzzi

**Fig. 115** Jacuzzi

**Fig. 116** Relaxing blanket

**Fig. 117** Relaxing tube

**Fig. 118** Promenade

**Fig. 119** Art on promenade

**Fig. 120** Relaxing on the wood

**Fig. 121** Sea gazebo

**Fig. 122** Jungle

**Fig. 123** Relaxing blanket

**Fig. 124** Clam and BUG (an area that was not protected and got corrupted by a griever)

This concludes our short idiosyncratic view to the varioty of things, processes, and expriences one can have in one version of a full 3D3C platform.

## 4 Time to Impact the Future

"We shape our tools and thereafter our tools shape us." Thus wrote Marshall McLuhan, author of "Understanding the Media". We can consider 3D3C platforms as a new medium, crawling and advancing, preparing to pounce on us in the next years. A medium combining entertainment, learning and work into one experience—that is its power and therein its danger.

Mitch Kapor, in his speech, delivered in the summer of 2006 at the Second Life Community Convention, emphasized a number of values from which I have freely extracted here. He stated (Rymaszewski et al., 2007, p. 306):

> "You are the pioneers and the founders of this new world, and you have unbelievably great opportunities to put your stamp, to leave a legacy, to create things which will endure and have value.
>
> The opportunity to participate in the creation of a new world is really a rare one and so I hope you cherish it... Any time you're involved with something radically new and disruptive, one of the major characteristics is going to be skepticism, or maybe, say, a struggle between faith and skepticism about this new thing, and the earlier it is, the more intense the struggle and more pitched the battle. ...
>
> With the privilege of creating a new world or new worlds, I believe, comes responsibility. And really, the responsibility is to make that new world a better place... which empowers individuals. My hope is that Second Life will continue to be a world that is more inclusive than the terrestrial world, and will enable groups of people that are marginalized in the real world to be first-class citizens and residents.

It's still very early. I'm hoping that inclusiveness and Second Life being a level playing field for everyone remains and increases as a core value. And finally I would just say to each of you, I hope you would think carefully about what a better world means to you, and as you go about Second Life you do things, build things, and interact in ways that further your own vision of that better world."

How true! 3D3C platforms are indeed a new medium: A medium of communication, experience and action; A medium in which human capabilities are augmented and supported by powerful digital forces. This societal potential is immense. I am rising to the challenge. How about you?

## References

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) ISSN: 1941-8477.

infinitemind. (2006a, August 7). *The making of Suzanne Vega's Second Life Guitar* [video file]. Retrieved from http://youtu.be/bQL8_HB1HtQ.

infinitemind. (2006b, August 7). *The Infinite Mind & Suzanne Vega "The Queen & The Soldier"* [video file]. Retrieved from http://youtu.be/WpGeRgkOUCE.

Rymaszewski, M., Au, W. J., Wallace, M., Winters, C., Ondrejka, C., & Batstone-Cunningham, B. (2007). *Second life: The official guide*. Hoboken, NJ: Wiley.

Bloomfield, R. (Ed.) (2007). *Playing Metanomics: Yesha Sivan* [video file]. Retrieved from http://archive.treet.tv/metanomics-dr-yesha-sivan.

Eldon, E. (August 1, 2007). Disney buys Club Penguin in $700 million deal—virtual worlds have arrived? [VB News blog post]. Retrieved from http://venturebeat.com/2007/08/01/disney-buys-club-penguin-in-700-million-deal/.

Marshall McLuhan. (n.d.). In *Wikipedia*. Retrieved October 26, 2014, from http://en.wikipedia.org/wiki/Marshall_McLuhan.

# Part I
# Tools

# The Raise of the Robots in Virtual Worlds: A Comparison and a Framework for Investigating Bots in Social Networks Sites and MMOGs

**Stefano De Paoli**

## 1 Introduction and Goal of this Chapter

The goal of this chapter is to develop and discuss a comparative framework for studying bots in Virtual Worlds (VWs), focusing in particular on Social Network Sites (SNSs) and Massively Multiplayer Online Games (MMOGs).

**Definitions of SNSs and MMOGs**

Social Network Sites (SNSs) are platforms used by people or organisations to engage with other people and organisation and share information. According to Boyd and Ellison (2007, p. 211) they are "*web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system*". Relevant SNSs examples are Facebook and Twitter.

Massively Multiplayer Online Games (MMOGs) are online gaming platforms often based on 3D immersive virtual environments that are played by a large number of players (Castronova, 2005; Taylor, 2006). The key goals for the players are to level their in-game persona or avatar and to engage in social interactions (e.g., forming guilds) with other players. These goals can be achieved by killing monsters or completing game quests. Relevant MMOGs examples are World of Warcraft and Eve Online.

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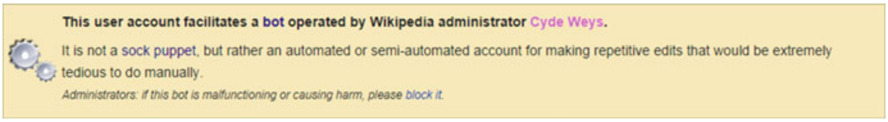


**Fig. 1** Explanation of the Wikipedia bot Cydebot, from http://en.wikipedia.org/wiki/User:Cydebot

Bots are computer programs that automate activities for the human user over the internet. Generally bots automate activities that are seemingly repetitive and that can be time consuming to be performed manually by humans. To a certain extent therefore bots emulate and replace human activities in a variety of online contexts, especially when tasks can be easily automated due to repetition. Bots are increasingly becoming a defining component of the Internet technological and cultural landscape. According to a recent research more than 60 % of Internet traffic is generated by bots (Incapsula, 2013). Often, bots are software programs with legitimate purposes and benign functions. They can help online communities or companies in carrying out repetitive and mundane tasks. Like other forms of automation—for example workplace automation—they allow to increase productivity by automating repetitive actions. For instance, Wikipedia is largely maintained with the support of bots (Geiger, 2011) that can automate repetitive and time consuming tasks and offer a possible solution to the seemingly declining human contribution to Wikipedia (Simonite, 2013). Wikipedia bots can for example be used to revert vandalism or to make simple edits to articles. These and other activities could be repetitive and tedious if performed manually and bots are devised by editors and the community to support the maintenance of Wikipedia. Figure 1 is a description of a Wikipedia bot called Cydebot, defined as an automated or semi-automated software for making repetitive edits that would otherwise be tedious to do manually.

Another example of benign and legitimate bots are Crawling bots, such as those used by search engines. They automate the process of web pages indexing, an activity which could be extremely time consuming, repetitive and expensive if performed manually by humans. Crawling bots have been of paramount importance for the development of search engines (Sonnenreich, 1997).

While benign bots are widely diffused over the Internet, VWs are often affected by bots that have malicious intents, causing harms, disruptions and illegal activities. Malicious bots in VWs share with legitimate bots a key aspect: they are an automation of repetitive and time consuming tasks. Certain aspects of MMOGs and in particular the so called avatar levelling, can be quite repetitive—with some authors claiming that this resembles industrial repetitive work (Yee, 2006). Bots can be used to automate repetitive game actions such as killing monsters for purposes of avatar levelling. This however is a form of cheating (Consalvo, 2007; De Paoli and Kerr, 2010) and it is an explicit violation of games Terms of Services (ToSs). The use of bots for avatar levelling clearly impacts on aspects such as the VWs community, for example by polluting social relations with a proliferation of unfair achievements for cheaters. These unfair achievements can easily unbalance the game, hence ruining the game experience for fair players. In some cases MMOGs bots are used to unfairly produce virtual assets and to accumulate virtual gold (i.e., gold-farming) that are sold over the internet for real money (an activity called Real World Trading—Heeks, 2009), again in violation of ToSs. Gold farming and the unfair accumulation of virtual assets is something that impacts on healthy and fair economic opportunities in MMOGs.

Malicious bots affect also SNSs and they are known as socialbots: automatic software able to entertain social relations (Gehl, 2013) and to build and even distort social networks (Hwang, Pearce, & Nanis, 2012), where in this second instance social networks is intended as the network of ties among social actors. Several actions of SNSs—such as awarding likes or following back other users—are also repetitive and time consuming especially in cases in which multiple accounts are used to engage with large customer bases. In SNSs, while some forms of automation are allowed or tolerated (e.g., scheduling tweets), there are bots that are used for deviant purposes such as obtaining privacy data in a deceptive way (Boshmaf, Muslukhov, Beznosov, & Ripeanu, 2011) or even intruding in organisations (Elishar, Fire, Kagan, & Elovici, 2012). Socialbots are also used to develop automatic marketing, leaning toward spam (NexGate, 2013), with the bots scraping user data and spamming users with unwanted content and advertisements. Also the use of socialbots is a violation of ToSs of SNSs.

According to official data, around 8 % of Facebook accounts could be managed by bots (Facebook, 2012) and 32 % of all tweets made by the most active Twitter users seems to be produced by bots (Sysomos, 2009). While not all of these bots have deceptive purposes, most of them have. Former research conducted on companies based in Italy, showed that bots are widely used to boost reputation and engagement on SNSs pages (Camisani Calzolari, 2012), with up to 46 % of companies followers being bots. For MMOGs we do not have the same clear data about the diffusion of bots, however it is not uncommon for game companies to ban tens of thousands (PCGAMER, 2012) or even millions of accounts linked with bots (PCGAMER, 2011). Furthermore, in both SNSs and MMOGs we have seen service providers initiating and in some cases also winning lawsuits against bot makers (Runescape, 2011; Twitter, 2012).

Given the diffusion and problems caused by malicious bots in VWs, it becomes relevant to investigate this phenomenon and develop conceptual tools for understanding the problem as well as for improving the practice. For the scope of this book, while MMOGs can be considered 3D3C Real Virtual Worlds as defined by Sivan (2008), SNSs are not. However, given the diffusion of bots in both SNSs and MMOGs and given the existence of clear similarities, a comparative research on bots in SNSs and MMOGs will strengthen our understanding on the phenomenon. This in turn will offer a greater impact on both the design and the research on 3D3C Real Virtual Worlds. Hence, the goal of this chapter is to develop an analytical-comparative framework for studying bots in SNSs and MMOGs organized around four main interconnected dimensions-concepts: automation, deception, policing and legal definitions. This framework is the result of a multi-year qualitative research endeavour and it is the outcome of an inductive analysis process, which will be described in the next section of the chapter.

## 2 Methods and Concepts: The Comparative Framework for Studying Bots in VWs

The comparative framework for studying bots in SNSs and MMOGs developed in this chapter is based on empirical research and data collected over a period of 5 years by the author. This chapter also builds upon a number of previous publications by the author (De Paoli, 2013a, 2013b; De Paoli and Kerr, 2012), including a paper published in the Journal of Virtual Worlds Research (De Paoli and Kerr, 2009).

For MMOGs, data will come from two case studies carried out since 2009: the MMOGs Tibia (http://www.tibia.com—research started in January 2009) and Runescape (http://www.runescape.com—research started in January 2012). This includes also data coming from bot makers' websites for these games. Official documents from game developers have also been collected, including legal documents. These cases have been investigated due to the proactive approach that game companies have against bots.

For SNSs, the author conducted a research on the use of bots with a focus on studying selected socialbot makers websites and the media representation (e.g., newspaper articles) of socialbots. Also for SNSs legal documents and official communications (e.g., company's blogs) where collected and analysed. Finally, an internet marketing forum (the Warrior Forum—http://www.warriorforum.com/) has been investigated for discussions about SNSs automation. Data collection on SNSs was conducted during the year 2012 considering the following SNSs: Facebook, Twitter, Pinterest, Instagram and Soundcloud.

Finally, a note is required on the data coming from bot websites, for both MMOGs and SNSs. Many of the bot websites studied by the author are now inactive or defunct. Since VWs companies are proactive in contrasting bot makers, using for example lawsuits or aggressive technical countermeasures, bot websites are quite volatile data. When a website or a bot is defunct it will be signalled within the text of the chapter.

All the data presented in this chapter has been analysed using Grounded Theory (Charmaz, 2006) and developing a theory as outcome of data analysis. Grounded Theory is an inductive analysis technique based on the idea of coding: assigning a meaningful code (a researcher interpretation) to a portion of textual data (e.g., portions of interviews or online forum discussions). From an initial set of codes, concepts can be developed and redefined leading in advanced analysis to the development of a theory. For this research, the concepts—i.e., the dimensions of the comparative framework—are the outcome of the analysis and they have been

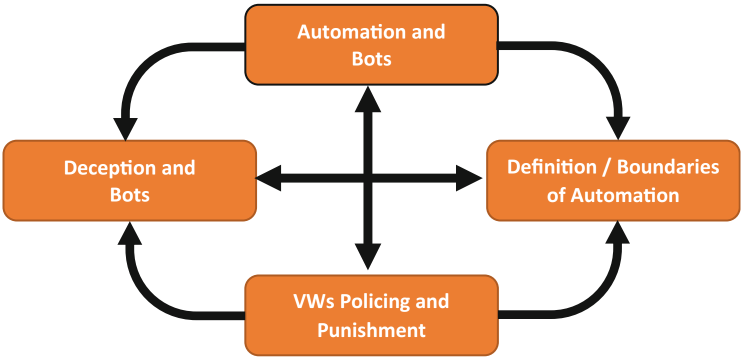


**Fig. 2** The interconnected dimensions/concepts of the comparative framework for studying bots in VWs

developed initially with an open coding and then with a refinement based on both a selective coding (for the Tibia case study) and an axial coding (for Runescape and SNSs research). The conceptual framework developed in this chapter via the Grounded Theory analysis is composed of the following interconnected dimensions or concepts (see also Fig. 2):

1. Automation and bots
2. Definition of bots & Boundaries of Automation
3. VWs Policing and Punishment
4. Deception and bots

The remainder of the chapter is organised around a discussion of each dimension of the conceptual framework and their interrelations. This discussion will be substantially augmented using empirical data. For each dimension a short theoretical perspective will also be provided for greater clarity and depth, linking this research with wider debates.

## 3 First Dimension: Automation and Bots

Automation is the first dimension of the comparative framework for studying bots in VWs. This section shows how the concept of automation relates with bots, initially by introducing a theoretical perspective and then turning to the analysis of data.

Automation is a complex concept and it is out of the scope of this chapter to provide an exhaustive overview. A definition that can be used as starting point comes from Marx (1976) and the chapter "*Machinery and Large Scale Industry*" of *The Capital* which offers a rich description of the process that lead to the automation of production of the manufacture system: a shift from handicraft work to its incorporation into early automatic machines. Marx's historical-materialist account offers a clear definition of the relations between automation and work that can be used for discussing some aspects of bots. According to Marx (1976 p. 495): "*The Machine, therefore, is a mechanism that, after being set in motion performs with its tools the same operations as the worker formerly did with similar tools.*"

This definition highlights an important aspect: industrial automatic machines can replace "*human labor*" with "*machine labor*". The machine performs the same operation of the workers with similar tools and produces output in place of the worker. In his analysis, Marx considered also some consequences of the automation of the work process, among these: (1) the deskilling of workers with their handicrafts skills being translated into machines; (2) the objectification of the production process with a reduction of workers to appendices of machineries; (3) capitalists' use of automatic machines for increasing productivity, having need to compete with other capitalists. In the remaining of this paragraph the issues of replacement of humans with automatic machines and productivity will be further considered, whereas an account on the issues of deskilling and objectification (in relation exclusively to MMOGs bots) is offered in De Paoli (2013b) and is not considered here in-depth.

**Deskilling and Bots in MMOGs**

In a paper entitled *Automatic-Play and Player Deskilling,* De Paoli (2013b) introduces the concept of *Automatic-Play* in order to conceptualise the deskilling process (Braverman, 1974) that links players and bots in MMOGs.

Bots in MMOGs are automatic playing technologies that replace several of the player in-game actions. Therefore bots exhibit skills that usually belong to the human player: this includes skills related with activities such as killing monsters or looting virtual gold. What we have is properly a translation of skills (Latour, 1987) from the human actor (the player) to the non-human actor (the bot). Once a bot is launched and actively used, players/cheaters become then the supervisors of an automatic technology that possess all the skills necessary to play. This is a process of objectification of play, since play does not depend anymore on the subjective abilities of the player and depends entirely on the objective capacities of the technology. Players using bots become appendices of these technologies.

The replacement of workers with machines is a process that frees resources that can be appropriated by the capitalist, via the means of a reduction of the labour-time required to produce the same use value. Productivity is the relationship between output of goods and services (O) and the inputs (I) of the productive process:

human resources (labour), and non-human ones (such as technologies, materials and capital in general). Productivity is usually expressed as the ratio Output/Input. Productivity increases can therefore be obtained by producing more in the same time, by replacing humans with machines. Furthermore, machines can work for extended times compared to workers, without impacting the input due to an extended production time. This also leads to an increased output in linear time (i.e., more can be produced in the same amount of days).

What was just described is a conceptualization of automation that offers something for theorising bots in VWs. It is possible now to read some definitions taken from socialbot makers' websites and consider them in the light of the above discussion about automation:

> Definition 1: SoundcloudRobot automates tasks you would normally do to grow your followers. (From http://soundcloudrobot.com/about/)

> Definition 2: Manually following Instagram users in hope that they'll follow you back is a pain. Even worse is unfollowing those that don't even bother following you! Save yourself some time and let our software automate this process for you 24 h a day. Your fan base will grow every time you wake up!
>
> (From a defunct bot for Instagram—data available at http://web.archive.org/web/20121209042441/http://instadominate.com/)

> Definition 3: Welcome to NinjaGram, the world's #1 Instagram bot. This proprietary and versatile marketing software handles all of the repetitive grunt work, SAVES you large amounts of time, gets you thousands of followers, and helps you generate more profit from this wildly popular image sharing website! (From http://ninjapinner.com/ninjagram-instagram-bot/)

In these definitions, the socialbots are framed as a substitution of human labor with machines, with claims like [the bot] "*automates for you*" or "*handles the repetitive work*". And the rhetoric used, explicitly points to the idea that actions on SNSs are repetitive and time consuming, with claims like "*grunt work*" or "*manually following is a pain*". Socialbots offer a number of human action/tasks replacements that could include the following: auto-add friend, auto-commenting, auto-like/pin, auto-follow, auto-unfollow or auto-posting. This list includes most common automation features of socialbots, but should not be considered as fully exhaustive. The following example shows how these generic features are advertised on a Pinterest bot webpage:

> Auto Follow feature that allows you to mass follow other users fast, gaining you thousands of followers back
>
> Auto Unfollow function that allows you to mass unfollow users that don't follow you
>
> Auto Pin feature that allows you to mass re-pin other images on autopilot getting you exposure
>
> Auto Commenter feature that allows you to send out comments to all others users.
>
> Auto like feature that allows you to mass like pins, boards, etc.
>
> (From http://ninjapinner.com/features/)

All these features can, according to the bot maker, "*Get you thousands of followers on Pinterest quickly on virtual auto-pilot.*", again an idea that points to a machine conducting the whole SNSs engagement process replacing human intervention. Therefore human actions on SNSs such as awarding likes and following are replaced by machines doing the same tasks of the user. Each of the above features provides increased output in a short amount of time: gaining followers fast, getting exposure, mass produce like or pins. Automated features of socialbots therefore allow extending a clear parallelism with automation of manufacturing: human labor tasks can be replaced with automation doing the same tasks for obtaining a greater amount of results. In the second definition (Definition 2) there is also a remark that the socialbot can operate 24 h without getting tired and easily overcoming the problem of not receiving traffic (i.e., people not following back). This allows producing results in less time compared to competitors that only work manually and therefore for few hours a day. In the third definition, the socialbot is marketed as a tool that allows to avoid "*grunt work*" while saving time and increasing followers and profit. This leads to "*massively increase*" of one's account activity. Automation is therefore directly connected with productivity and growth of traffic on a social media accounts. This is a comment taken from a bot website, described as a "testimonial" and therefore (at least in theory) a comment from a socialbot user:

> FINALLY! I am no longer spending time in front of my mobile screen doing Instagram marketing! It was a pain and I'm so glad I found this software. I'm saving countless hours each week AND I am driving in organic traffic into my website—thank you so much.
>
> (From a defunct bot—data available at http://web.archive.org/web/20121209042441/http://instadominate.com/)

Again, there is the conceptualization of the socialbot as a replacement of human labor with machines ("*I am no longer spending time in front of the screen*"). The reason for adopting a socialbot lies in the repetitive and time consuming actions ("*it was a pain*"). Further, the software allows getting the same output ("*driving traffic*") but with reduced input ("*saving time*").

In MMOGs bots are also used to replace human activities with automation. Bot makers in MMOGs are much more sparingly offering long definitions as in the case of socialbots, however, well known bots for Runescape are for example marketed as "*leading automation for Runescape*" or as a technology that "*Emulate & automate any challenge in-game*" or as "*the ultimate automation software*". The following are examples of descriptions of bots:

> By automating the manual and repetitive aspects of the game you can set Powerbot 07 to work on any skill, task or activity and enjoy an account with high level stats and a wealth of resources.
>
> (From http://powerbot07.net/download/index.html)

> Our premium bots allow you to safely enjoy RS without having to go through the countless, tireless hours of developing your characters
>
> (From a defunct bot for Runescape—data available at https://web.archive.org/web/20100612060002/http://www.rsbots.net/runescape-bots)

The bots in Runescape (e.g., RS) are used to perform the same repetitive and tedious tasks that a player does: the bot automates repetition for the human. The bot allows the user to "enjoy" the game, however, and this is the key aspect, the avatar levelling and development is done with substantial amount of time saved. Again automation is a way of increasing productivity, with the same output (a fully developed avatar) being readily available in short amount of time with a bot (input). Similarly to socialbots, MMOGs bots have features that are used for automation of repetitive tasks. More often these automations are specific scripts that work in conjunction with a core bot platform. In other words, the bot user purchases or downloads the core software of the bot which supports the main calls to the gaming platforms and then the user can purchase scripts tailoring the core bot software with her specific needs, e.g., a script automating fishing or a script automating harvesting. A glimpse at the scripts marketed by one of the major Runescape bot makers offers a view of the type of tasks that are automated (http://www.powerbot.org/scripts/#premium), some of which include: Auto fishing, Auto fire-making, Auto Magic as well as scripts that do not directly contain the word "*auto*", but which nonetheless automate activities such as collection of loots or divination. A bot in MMOGs has therefore relevant parallel with a socialbot for SNSs as it is a replacement of human playbour (Kücklich, 2005) with automatic play (De Paoli, 2013b): an automation software carrying out the same repetitive game tasks with similar tools of players.

In both SNSs and MMOGs we have therefore a similar rhetoric surrounding productivity that the replacement of humans with technologies can achieve. We can further observe this aspect from some excerpts from forum discussions, this time taken from the MMOG Tibia:

> My main point is this: botters get high levels in a short amount [sic] of time, and because of that, they abuse of their power to either corrupt the community or break it apart.
>
> [Posted on Tibia forum, 20/09/2008]
>
> When some bunch of idiot kids bot 24/7 and do what took me years to accomplish in terms of magic level and level in a few weeks, that annoys the living hell out of me
>
> [Posted on Tibia forum, 01/02/2009]

In the second case the playbour time is framed using the idea that the bot can play for extended time compared to human players. 24/7 play means that a character is played for an extensive time, not just for 1 day but often for weeks or months. We saw the issue of productivity framed in exactly the same manner in socialbot definitions (i.e., Definition 2), with the socialbot being able to operate 24 h a day. We also clearly see how players perceive bots as a threat to the community dynamics (corrupt the community) of the VW.

We can draw therefore a conclusion: that bots in VWs—be they for SNSs or MMOGs—can produce outputs (e.g., avatar levels, social engagement) for an extended time, compared to humans. This peculiar aspect allows bots to engage and build a social network of connections or to level an avatar, while the owner of the account is not at the computer screen and while the other human competitors need to rest or attend their real life. Likewise the productivity is also enacted in a different way: the same output—a fully developed avatar or a social network of connections—can be achieved by robots in short amount of linear time.

## 4 Second Dimension: Bots in VWs Documents and the Boundaries of Automation

The second dimension of the comparative framework is the definitions of bots offered in official documents of VWs. These definitions set and define the boundaries of what type of automation is allowed and not allowed in VWs and why. In the previous section, bots in VWs have been characterized as automation of repetitive activities replacing human labor. However, this aspect is not different from other legal bots, for example Wikipedia bots are also meant to support a community with repetitive and time consuming tasks, allowing to maximize effort. There is something different, therefore, in malicious bots for VWs and this is the idea that increases in productivity triggered by (certain forms of) automation, create a process of unfair or unethical competition among participants. The following is a newspaper article excerpt that frames the problem in the case of Twitter:

> You can't argue that the whole idea of supplementary Twitter applications is to give you distinct advantages over the official interface. You can reach followers on the other side of the planet who would normally be asleep during your active hours, you can multiply the number of actions you're capable of completing on any given day, you can live a normal life and still portray yourself as a Twitter super user, and you can use advanced filters to make it all more efficient. The question isn't whether or not it works; it's whether having access to the social networking equivalent of steroids is ethical (From http://socialmediasun.com/twitter-ethics/).

According to the above excerpt, the owner of a socialbot has an unethical and unfair advantage over those who do not use bots. The reason for this is that a socialbot allows the owner to reach followers and multiply activity on an account, when "purely" human competitors need to attend their normal life. An advantage which is, by analogy, comparable to the use of drugs in sport competitions (i.e., steroids). Indeed, we can imagine a situation in which two competing organisation are building a marketing campaign with SNSs, focusing on reaching potential customers and increasing traffic to a page. In this case if one organisation uses forms of automation it will be able to engage users 24/7, day and night.

That of unfair competition and the analogy of using illegal drugs in sport competition is a rhetoric that can be easily found also in MMOGs, the following is an excerpt of a forum discussion among players taken from the Tibia forum:

> When someone uses a bot to hunt, it's like an athlete taking steroids.
> [Posted on Tibia Forum, 01/03/2008]

Using a bot to level an avatar (i.e., hunt monsters in the above excerpt) creates unfair competition and similarly preserves the analogy of an athlete taking steroids. In MMOGs clearly players compete to reach results and the use of bots unbalance the process, with owners of bots being able to develop their avatars or to accumulate virtual assets in a short amount of linear time. This can also be achieved by using several bots controlling several puppet avatars whose virtual assets are later transferred to a main character that might be played legitimately by bot's owners.

In VWs we have rules that explicitly forbid the use of (most forms of) automation. These rules are contained in legal documents of VWs such as ToSs, Privacy Rules, and Game Rules. This chapter does not use a legalistic perspective but a sociological and criminological perspective to consider this problem. In this perspective, a key idea is that of "social construction", a process in which social actors shape the social world around themselves and this could include social institutions, scientific knowledge and also social rules. In this perspective "criminal" or "deviant" is the act that contravenes the law or the informal norms of a social group and the definition of "right" and "wrong" is the outcome of a social construction process. Becker (1963, p. 1) in a seminal work entitled *Outsiders Studies in the Sociology of Deviance* stated: "*All social groups make rules and attempt, at some time and under some circumstances, to enforce them. Social rules define situations and the kinds of behavior appropriate to them, specifying some actions as "right" and forbidding other as "wrong"* ". Therefore, the definition of a deviant act does not necessarily come from abstract rules and it tends to reflect economic, cultural or political developments within the same group (Burke, 2013).

It is possible to approach the problem of the "wrong" nature of bots in VWs and therefore to understand the boundaries of what is permitted in terms of automation using the social constructivist perspective. Indeed the principles guiding the decisions about the rules may vary depending on the VWs and the actors involved. There exists for example some VWs in which automations are tolerated.

ToSs of VWs generally forbid the use of bots, seen as a form of unfair competition over those that do not have automation and also something that ruins the experience of a game or SNSs. Furthermore, VWs often see the use of third party software application as a threat to: (1) the information security of VWs, since often they exploit weaknesses in the code or in the trust relations; or (2) to user privacy, when they are used to automatically scrape user data. Only the aspect of unfair competition will be considered further here, whereas an excellent paper on the issue of Privacy is Boshmaf et al. (2011) and the issue of trust is discussed in both Boshmaf, Muslukhov, Beznosov, & Ripeanu (2012) and De Paoli (2013a).

Different SNSs have different approaches and definitions of what is a bot or an automated software and what constitute a "wrong" action in this area. The following is a term (Tos) from the SNSs Soundcloud:

> (v) You must not employ any techniques or make use of any services, automated or otherwise, designed to misrepresent the popularity of Your Content on the Platform, or to misrepresent your activity on the Platform, including without limitation by the use of bots, botnets, scripts, apps, plugins, extensions or other automated means to register accounts, log in, add followers to your account, play Content, follow or unfollow other users, send

> messages, post comments, or otherwise to act on your behalf, particularly where such activity occurs in a multiple or repetitive fashion.
>
> (From https://soundcloud.com/terms-of-use)

Soundcloud is quite explicit in forbidding the use of bots and other automated software as replacement of humans ("*to act on your behalf*"). The key justification is that bots and other automated means such as macros are used with intent towards manipulating certain metrics such as the number of followers. Bots are therefore forbidden explicitly because they offer a mean to artificially increase certain outputs within the SNSs. They are explicitly declared to "*misrepresent the popularity and activity*" of an account. Pinterest also offers a similar justification (in the Acceptable use policy) stating that it is forbidden in general (and also with socialbots therefore) to:

> Pin large amounts of unwanted or repetitive stuff, post unsolicited commercial messages in comments, descriptions, etc., or try to artificially boost views, Pins, comments or other metrics
>
> (From http://about.pinterest.com/en/acceptable-use-policy)

Elsewhere, the author of this chapter defined this process as the *Automated Production of Reputation* (De Paoli, 2013a): the idea that aspects such as online social influence, popularity and indeed user reputation can artificially and unethically be increased with automated means. However as reputation is being manipulated with automated technologies this could lead to a breakdown of trust in VWs.

Differently from other SNSs, Twitter is much more permissive with regard to certain forms of automation and has a document called *Automation Rules and Best Practices* that states:

> We're constantly amazed by the applications and services that develop around the Twitter platform.
>
> (From https://support.twitter.com/entries/76915)

Automation and third party software programs can be part of the Twitter experience as they offer solutions to problems and enhanced use of the SNS. On the same page, Twitter offers also some examples of good automation. However, the same document, right after the above sentence clarifies explicitly:

> However, spammers also take advantage of automation.
>
> (From https://support.twitter.com/entries/76915)

There is therefore a line that needs to be drawn between acceptable automation and automation as spam, at least in the case of Twitter. The following excerpt is again from the *Automation Rules* and is a list of automated behavior which is not allowed and considered spam:

> If you have followed a large amount of users in a short amount of time;
>
> If you have followed and unfollowed people in a short time period, particularly by automated means (aggressive follower churn);
>
> If you repeatedly follow and unfollow people, whether to build followers or to garner more attention for your profile;

> If you have a small number of followers compared to the amount of people you are following
>
> (From https://support.twitter.com/entries/76915)

There are therefore explicit actions that are forbidden in general, but there is attention to actions that are done "*particularly with automated means*" as detailed in the second point of the bullet list. Twitter also set limits, some of which are public such as the limit of following no more than 1000 users per day. Other limits are instead not public, such as the calculation of ratio follower/following, which is used for calculating the total number of users that can be followed with an account (a number which is set at 2000 for newly created accounts). These limits are detailed in the document *Why Can't I Follow People?* (https://support.twitter.com/entries/66885-i-can-t-follow-people-follow-limits). However reversing these limits it can be concluded that automation that do not contravene the above rules is allowed. If a bot has a reasonable following pattern, it should not raise suspicions. Later in this chapter this problem will be considered further as bot makers often try to exploit these rules in order to build their automations.

MMOGs have a similar approach in defining "*right*" and "*wrong*" in relation to bots. The following term comes from the Tibia Rules:

> Keep in mind that you are supposed to play the game yourself, not to have a tool or program play it for you. Doing so gives you an unfair advantage over players who invest time and effort to gain power. Using unofficial software such as a macro program or a so-called "tasker" or "bot" to automatically execute actions in Tibia for you may lead to a punishment. Thus, play fair.
>
> (From http://www.tibia.com/support/?subtopic=tibiarules&rule=3b)

This term is quite descriptive compared to the more legalistic jargon of SNSs. It starts by outlining a key aspect of automation: bots are a replacement of humans with technology for playing the game. However, it is exactly this replacement that contributes to drawing the line between "*right*" and "*wrong*": the rule states that a player is "*supposed to play the game*" and not a program. The problem of using a bot is that it offers an unfair advantage also, as human players invest time and effort to develop their avatars when instead bots can do so almost effortlessly. What follows is a Term taken from Runescape:

> Software that can be used to gain an unfair advantage in our games may not be used. This includes automation tools, macros, bots, auto-typers and any other tools that circumvent any of our mechanisms designed to automatically log out inactive users.
>
> (From http://services.runescape.com/m=rswiki/en/Macroing,_and_third-party_software)

In this case, the replacement of humans with machines is not recalled explicitly as for Tibia and the term points more directly to the problem of an "*unfair advantage*" as well as to the security issues that using a third party software may generate. It is important to outline that game ranks can also be seen as a form of (competitive) reputation system (Farmer and Glass, 2010) and using a bot to manipulate the game rank—which in both terms is the explicit justification for considering a bot "*wrong*"—is again a case of *Automated Production of Reputation* (De Paoli, 2013a), with machines producing experience points that contribute to manipulated increases in the game ranks.

Analysing the data, it was possible to observe that, in SNSs in particular, the definition of what falls outside the rules in terms of automation is often connected with what constitute a "*genuine participation*" or an "*authentic interaction*". Now these adjectives are taken directly from how SNSs define the problem. An important aspect of socialbots is that they are often marketed as technologies that create "*real*" social network of followers, versus instead networks of fake followers. This is how a bot maker frames this, over a YouTube account:

> Build THOUSANDS of VERY TARGETED and REAL HUMAN FOLLOWERS in few days
>
> (From https://www.youtube.com/watch?v=jUv26dsu6QI)

The idea appearing in SNSs legal documents, however, is that an interaction taking place with a socialbot or by the means of manipulated activities (e.g., likes awarded by machines, fake likes or even having a follower base of bots) is not "*authentic*". It does not reflect what should be considered as "genuine", from the view point of the service provider. Following is an excerpt from a Pinterest blog post:

> Keeping Pinterest authentic is vital to helping people discover the things they love. That's why we've built a dedicated spam team that has been hard at work investigating reports and building systems that detect, remove and prevent spam.
>
> (From http://blog.pinterest.com/post/37347668045/fighting-spam)

Spam activities (which include bots) are an obstacle to keep authenticity in Pinterest and the owner of the platform acts with investigations and automatic systems to keep interaction authentic. The SNS here makes a clear connection between the need for an authentic experience and the policing activities that are enacted for achieving this goal. Other SNSs such as Instagram use the sentence "*genuine and meaningful interaction*" for defining the same problem. This can be found in the Instagram Community Guidelines document (https://help.instagram.com/477434105621119/). Facebook also clearly states the importance that connections need to be "*authentic*" and that these connections need to involve a "real person" and not a fake one (https://www.facebook.com/notes/facebook-security/improvements-to-our-site-integrity-systems/10151005934870766). Activities that tend towards manipulation and spam are against an "*authentic*" and "*genuine*" SNSs experience.

In MMOGs we do not find the idea of *authentic interaction*, mainly because interactions are not the focus of these VWs. However, bots modify the game experience for the player community in ways there are not intended by the developer: the presence of bots alter the playful atmosphere and the balance of a game. Similar rhetoric therefore can be traced in the game companies' discussions about bots. For example early in 2009 the developer of Tibia published an article discussing its strategy against bots:

> In short, we do not want cheaters in Tibia. We are of the opinion that they directly destroy the economy and have a negative influence on the peaceful gameplay of fair players.
> (From http://www.tibia.com/news/?subtopic=latestnews&id=910)

The company states that it is working hard to prevent the use of bots that "*destroy the economy*" and negatively influence "*peaceful gameplay*". We see here clearly how the company considers the negative impact of bots on both commerce and community. Even if the same words of SNSs are not used the meaning appears quite similar: there are external objects that are being used that disrupt the integrity of the MMOGs experience. Where we can find a direct connection to the idea of a "*genuine experience*" is however in the comparison between bots and humans. This is a forum post from one of the Runescape Moderators:

> We will continue to evolve our anti-botting measures to hunt down those guilty of trying to spoil the game for genuine players.
> (From http://services.runescape.com/m=forum/forums.ws?294,295,84,64013824)

A game account which is used in conjunction with a bot is not directly controlled by what is defined as a "*genuine player*", therefore those guilty of using bots will be hunted down by the game company since they spoil the game experience. The same opposition between genuine (humans) and non-genuine (bots) players is often used in player discussion on the forums:

> These bots diminish and devalue the achievements of genuine honest players.
> [Posted on Runescape General Forum 07/07/2011]

Genuine players are opposed to non-genuine sorts (i.e., bots) and the latter spoil again the game experience since they diminish and devalue the achievements of the former. An idea that directly points to the problem of bots being a form of unfair competition.

In conclusion, the idea of "authentic and genuine" experience is a relevant concept for understanding the social construction of what is "*right*" and "*wrong*" in a VWs: there is a boundary between humans use of the VWs opposed to the machine use, with only the former being the one considered legitimate and authentic by the holders of legal documents.

## 5 Third Dimension: Policing in VWs

Directly connected with the social construction of the rules is the process of enforcing these rules. This is a third dimension of the comparative framework for studying bots in VWs. For Becker (1963, p. 122): "*enforcement of a rule is an enterprising act. Someone—an entrepreneur—must take the initiative in punishing the culprit*". In the case of VWs, the same service provider often acts as moral entrepreneurs. They are both the holder and enforcer of legal documents.

Within VWs we have witnessed an increased use of automatic software for policing. Both SNSs and MMOGs use automatic systems for monitoring the platforms, together with a degree of human decision: the goal being the detection of bot usage and subsequent punitive actions. Facebook for example has the so called Facebook-Immune System (FIS), a technology that (Stein, Chen, & Mangla, 2011):

> analyzes every action on the site as it happens, to determine its threat level, and decide how to respond. To make this decision it looks at the reputation of the cookie, IP address, and a number of other factors.

The FIS is an intrusive technology that monitors all the user actions taking place on the SNS in order to determine a threat level and take further actions. The system uses both user direct feedback (user reporting) and automatic monitoring:

> the system has knowledge of aggregate patterns and what is normal and unusual. This facilitates anomaly detection, clustering, and feature aggregation.

This technology acts therefore like a panspectron (DeLanda, 1991) collecting information about everything and taking actions based on specific queries. Therefore the FIS also (but not exclusively) tries to determine socialbot activities, together with spam activities or phishing. Further, details on the functioning of the system can be found in Stein et al. (2011). Knowledge about monitoring systems for other SNSs—and especially how they work—is comparably scarce than for Facebook, but for instance both Pinterest (http://blog.pinterest.com/post/37347668045/fighting-spam) and Twitter (https://support.twitter.com/entries/68916-following-rules-and-best-practices) explicitly claim to have monitoring systems against spam. With Twitter apparently working also on real time, predictive solutions (https://twitter.com/dickc/status/101427418832699392).

MMOGs employ a similar strategy of policing with increased use of automatic technologies for monitoring behavior in the game (Kerr, De Paoli, & Keatinge, 2014). Both Runescape and Tibia have monitoring tools that are used for detection of bots. The following is an excerpt from a forum post from a Runescape Moderator:

> Whilst I can't go into detail (as we don't want to give away any of our secrets), I can assure you we have *extremely* comprehensive macro behaviour detection tools and a dedicated team which reviews all accounts flagged before applying punishments.
> [Posted on Runescape General Forum, 20/10/2010]

Therefore policing activities in MMOGs are also delegated to automatic technologies that monitor behaviors that are suspicious or are known to be possibly malicious. In both SNSs and MMOGs therefore there is a technology based on a comprehensive suspicious behavior detection that coupled with a human revision of the tool analysis could lead to application of a punishment for bot users and their accounts.

Both SNSs and MMOGs impose punishments in case of rule violations. In society, punishment has a clear social function: "*Those who break the rules benefit without contributing. They gain personal advantage by doing what the rules* *forbid*." (Cragg, 1992, p. 13). Therefore, what obtained by breaking the rules needs to be balanced back by punishment. In the case of bots this imbalance is explicitly connected with increased results due to unethical competition as well as with ruining an authentic and genuine experience.

The following is an excerpt from Tibia, and in particular an announcement of punishment:

> These accounts have been identified by an automatic tool with complete accuracy, therefore any complaints about these punishments are in vain.
> (From http://www.tibia.com/news/?subtopic=newsarchive&id=921)

The monitoring tools contribute to an accurate identification of bots and based on this a punishment is triggered. Punishments in MMOGs may vary depending on the games and are also subject to negotiations with the player community. Elsewhere (De Paoli and Kerr, 2012), the author of this chapter discussed the problem of a punishment system reform in a MMOGs, showing also how punishments for bot users might be perceived as unfair by fair players (i.e., punishments do not re-balance the harm).

The MMOGs under scrutiny here both apply temporary bans for first detection and in cases of serious-multiple violations, the permanent suspension or even the final deletion of an account. Therefore in serious cases of violations, there is no coming back to the VWs for the account. MMOGs however have different punishment systems—again something which points to a social construction process related with different cultural or economic goals—and each game might have specific arrangements, for specific situations. For example in Runescape, the use of bots may lead to reduction of the experience points of an avatar (i.e., what obtained by using a bot might be taken away—Fig. 3), whereas in Tibia this punishment does not exist (even if it was demanded by the player community).

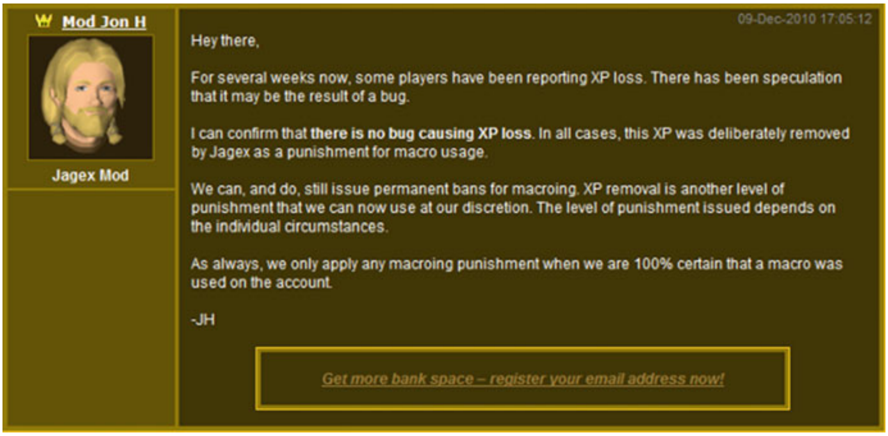


**Fig. 3** One of the Runescape Moderator confirming on the forum about reduction of levels for avatars. From http://runescape.wikia.com/wiki/File:Mod_Jon_H.png

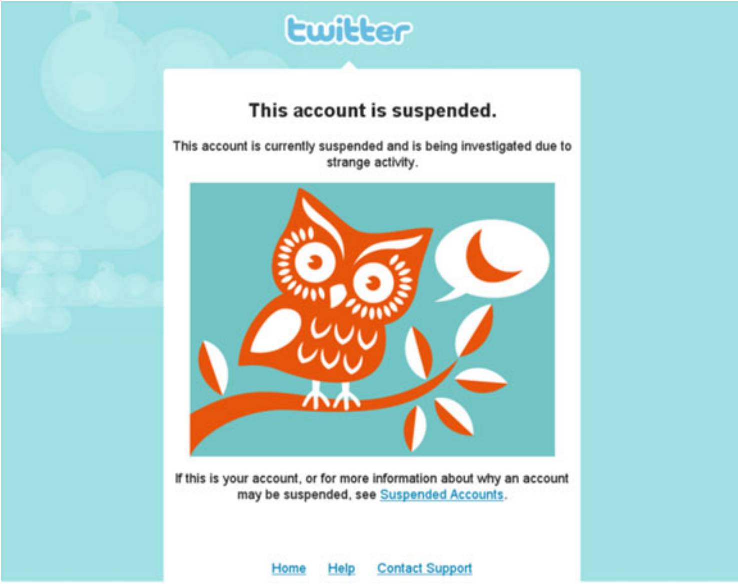


**Fig. 4** Announcement of an account suspension and investigation in Twitter, for "strange activity"

Or again, in Runescape it is possible to "buy-back" for real money an account permanently suspended for the use of bots, whereas this is not possible in Tibia.

In SNSs the situation is for some aspects comparable to that of MMOGs. For example, Twitter allows certain automations but forbids others that display a spam behavior, such as aggressive following and mass unfollowing. Twitter has a clear punishment rule for this type of behavior:

> Technical abuse and user abuse is not tolerated on Twitter.com, and will result in permanent suspension. Any accounts engaging in the activities specified below are subject to permanent suspension.
>
> (From https://support.twitter.com/entries/18311-the-twitter-rules)

Whereof the "*activities specified below*" is the list of aggressive/automated spam behavior seen before (including the automated following churn), plus a number of other behaviors (such as the distribution of malware or pornographic material) (Fig. 4).

Therefore, the permanent suspension for an account (i.e., not coming back) is the type of punishment applied for very aggressive behavior, although this is not often directly done and Twitter offers the opportunity to discontinue abusive behavior. An example of warning, offering to discontinue abuse can be seen here: http://blog.tweetsmarter.com/wp-content/uploads/2012/05/Chris-Loesch.png. In some cases Twitter also issues warning, for example with flagged URLs: https://support.twitter.com/groups/55-troubleshooting/topics/231-tweets-direct-messages/articles/90491-my-website-is-being-flagged-as-malware-or-spam.

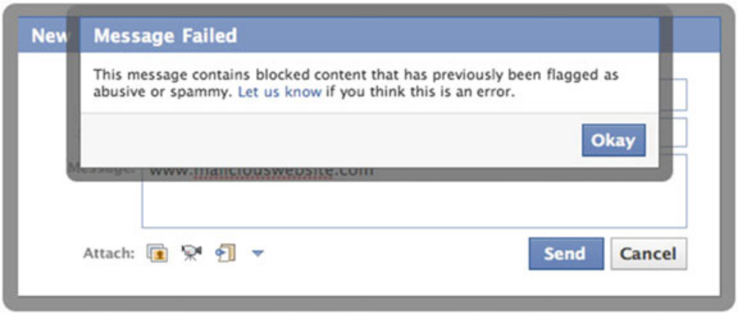


**Fig. 5** Facebook warning for spam

Facebook also operates in a similar fashion. When the FIS detects the rule violation, Facebook offers initial warnings to the user, reminding them to use appropriate behavior. However, as Facebook explains:

> In extreme cases where the behavior continues despite our warnings, we may disable the person's account. (From https://www.facebook.com/notes/facebook/explaining-facebooks-spam-prevention-systems/403200567130)

Therefore, with continuous violations, Facebook "disables" the account and again there is no coming back. This approach of SNSs is closer to the one adopted by MMOGs, which seems to have the goal of retaining customers offering them an opportunity for "redemption" from misbehavior with what in literature is defined a "forward looking" approach to punishment.

While this short excursus is not exhaustive and further research is required, it also shows a key aspect in the policing process against bots in VWs (and other violation of rules in VWs). There is initially an investigation process which is increasingly becoming automated (Kerr et al., 2014), through which secure proof of the rule violation is gathered. If the evidence is sufficient this leads to a punishment. Punishments may vary depending on VWs, but in all cases, where there are serious and multiple violations, the account might be terminated (Fig. 5).

## 6 Fourth Dimension: Deception and Bots

Bots in VWs disguise themselves as humans in order to remain undetectable to automatic monitoring technologies: this is the fourth dimension of the comparative framework proposed in this chapter. This is a fundamental aspect, especially in the marketing of bots as solutions for managing accounts in VWs. Indeed, while automation features are relevant, what consumers of these technologies are looking for is also a high level of "undetectability", in order to not suffer from punishments.

Bots have clearly some resemblance with the early automations for production as detailed previously in the chapter. However, differently from "ancestor automata", new automatic technologies possess reception organs with which they can receive a message and take action based on that message (Wiener, 1988). In *Understanding Media*, McLuhan (1964) argues that the key aspect of the automation in the electric age is the notion of feedback: the process in which there is a dialogue between the mechanisms and its environments. This mechanism says McLuhan: "*tends to raise itself to the level of conscious awareness, so that computers seem "to think"*." (p. 383).

Bots in VWs need to disguise themselves as humans and display to automatic monitoring technologies human-like behaviour in order to be viable in the bot market. This is necessary if bot customers are to avoid punishments. The following is an excerpt taken from the website of a (now defunct) bot:

> "Why does the bot stop and count down for an hour? Instagram has hourly limits on follows, likes, and comments on a per account basis. Botstagram is not designed to break the rules of Instagram. It stays within those hourly limits, so after each account has ran, it will count down for 1 h and then start again." (From a now defunct Instagram Bot—no URL available)

The bot operates within the limits and rules that are set by the SNSs, in order to remain undetected. In some SNSs aggressive following and other behaviors are monitored and punished. However making the bot behaving within the limits of the rules, makes the monitoring much more complex and offers to the bot user a technology which should be safe from punishments. The following is a similar excerpt from a Twitter bot, which suggests how the bot can take decisions based on external dynamics of the SNSs:

> Dont Get Your Account Banned
>
> [. . .]
>
> follow and unfollow requests are done using your web browser to appear more natural
>
> Assign different proxies for each account
>
> Put delay on every follow and unfollow requests
>
> Put limit to the number of users to follow
>
> Option to not follow users that are unfollowed before
>
> Unfollow users followed at least the specified number of days
>
> (From the defunct web page of a Twitter bot—data available at http://web.archive.org/web/20110411105335/http://tweetattacks.com/)

The bot in this case offers a series of features most of all intended to comply directly with the Twitter Automation Rules. There are features meant to make an account appear natural in the behavior, such as delays in follow/unfollow, that offer opportunity for non-mechanical behavior (i.e., following someone after the same time interval) or limitations in the number of followers (limitations per day, to remain within the limit allowed by the SNSs). There is also an explicit remark that this allows to avoid punishment (*Don't Get Your Account Banned*). In forums devoted to Internet marketing (e.g., the Warrior Forum) discussions around limits of SNSs and about how to use socialbots within these limits, are quite frequent:

> Remember to keep your ratio at 1:1.1 max followers/following after you pass 2000. One of the best parts of Tweet Adder is that it shows this ratio and will stop following or unfollowing at any specific ratio you set.
>
> (From Warrior Forum: http://www.warriorforum.com/main-internet-marketing-discussion-forum/245663-twitter-question-2001-following-limit-real-fake.html)

This example, is extrapolated from a discussion about the ratio follower/following that one can use after he/she has reached the initial limit of 2000 following and what the SNS allows to do in term of aggressive behavior. The poster remarks a rule for appropriate ratio and offers indication for a bot (TweetAdder) that monitors this ratio. The key aspect is that socialbots need to behave within the rules in the "eyes" of monitoring technologies and actually this is a fundamental aspect for a socialbot to succeed in the market.

In MMOGs the connection between bots and deception is very comparable to SNSs: bot makers seek to develop and market technologies that behave like humans in the eyes of the monitoring technology. Actually, users are looking mainly for bots that have a high degree of undetectability in order to avoid punishment. The following excerpt is from the website of a (now defunct) bot for Tibia:

> The bots are actually perfect, but none player is perfect, bots needs [sic] to make mistakes as we do, needs to "forget" some loots as I already did, "forget" to spell an exura and remember some mana after the mark [From a now removed webpage of a Tibia bot—URL not available]

There is a clear remark that the bot can act perfectly, but humans do not always act in the same manner and "*make mistakes*" and "*needs to forget*" to do things. Therefore this specific bot was programmed to act in the same manner as a human. The Tibia case study is particularly relevant since during the research, the game company introduced a brand new monitoring tool and some bots became easily detectable. After the introduction of the monitoring tools, all of the Tibia bot makers entered in a process of innovation of their technologies (De Paoli and Kerr, 2009) aimed at bringing to the market more secure bots, able to remain undetected. It is interesting to see how these new technologies were framed in the bot forums:

> [the bot] will go stealth and there will be no possible counterattack for my method. Now working on adding chaos to all timers. Heal chaos done Runemaker chaos done Now working in cavebot chaos. Bot will simply act as a human.
>
> [Posted by the bot maker on the bot Forum, 02-06-2009]

The technology of the bot therefore is improved in ways that will make the bot appear more like a human. In particular a chaos function is being introduced for making the bot act in a randomised and chaotic way, rather than in a mechanical way.

In conclusion, we can draw again a strict connection between deception in socialbots and bots in MMOGs. These technologies are developed for automation purposes, but their defining aspect is the ability to remain undetectable to existing monitoring technologies. This is necessary if bot user are to avoid punishments from VWs service providers.

## 7 Discussion and Conclusion: The Raise of Robots in VWs and Next Research Steps

In a *Social Media Today* article criticizing the use of automations in Social Media, McCaffrey (2011) offers—among others—this justification for avoiding automation on SNSs": "*No one wants a relationship with a robot*", since relationships need to be among real people. This is a re-proposition of the idea of authenticity and genuine interaction discussed earlier in the chapter. However, despite the clear desire for authenticity in VWs, reality seems to be clashing with this. Indeed, already in 2011 a prediction by Gartner (2010) stated that "By 2015, 10 percent of your online 'friends' will be nonhuman". We saw before that official data from Facebook are indeed close to this prediction (8 % of accounts managed by bots). Increased capabilities of socialbots (Boshmaf et al., 2011), new cutting edge research being conducted in the area of socialbot development (Hwang et al., 2012) and companies managing extensively their online presence with automated means (Camisani Calzolari, 2012), are contributing to making this prediction true. It is clear that bots are becoming a relevant aspect of the VWs experience that impacts communities, creative processes and wealth creation. Deceptive robots are on the rise in VWs. Research and scholarship in this area, therefore, are needed to explore the developments, problems and solutions to this issue.

The goal of this chapter was to propose a framework for studying bots in SNSs and MMOGs in a comparative perspective. It is the outcome of a multi-year qualitative empirical research. This framework is organised around four—deeply interconnected—concepts each pointing to a key aspect of bots: automation, deception, policing and legal boundaries of automation. While these four concepts might not necessarily be fully exhaustive of the phenomenon, they also cover a lot of ground and allow to comprehend the complexity of bots in VWs. Bots in VWs are automations that replace humans in repetitive tasks and that allow increases in productivity and outputs. These aspects however contribute to making bots a form of "*unethical and unfair competition*", explicitly forbidden by legal documents of VWs. The existence of rules is related to their enforcement, which in VWs sees an increased use of automatic monitoring tools and different forms of punishments, all leading in the extreme case to the cessation of the account. Deception is therefore designed and implemented in bots in VWs, for avoiding both automatic monitoring and punishment.

The framework proposed in this chapter should not be considered as a theory from which to deduce provable hypotheses, rather it is more of a map that can be used for guiding future research on the subject. It is helpful for identifying trajectories and paths that might require further investigation as well as for organising existing research on the subject. Furthermore, the comparison framework is flexible enough to be used in conjunction with theories and approaches that are different from those used in this chapter: for instance the issue of legal documents could be linked with more legalistic approaches or the idea of authentic participation could be linked with existentialism (Heidegger, 1927).

From this analysis one important aspect clearly emerges: bots in MMOGs and Socialbots in SNSs converge in many ways. Each has clearly some peculiar aspects, since the latter are intended to build relations whereas the former are used to level an avatar. However, the technological framings (automation, productivity and deception) and the problems faced by VWs (legal definitions and policing) are very similar. Streams of research analysing bots in MMOGs and socialbots in SNSs need therefore to work closely together, if we are to offer appropriate research on this phenomenon.

Where to take this framework from here? The research on bots is still in its infancy in many areas. This chapter points to possible further research trajectories. For example, a research by Camisani Calzolari (2012) pointed that companies seem to use quite widely socialbots on their social media accounts. However, no extensive research to date has emerged accounting for this practice: will socialbot replace human community managers, for example? And how? Another area of investigation relates with punishment. Elsewhere, I offered an analysis of rational punishment for the MMOG Tibia. However, we do not have fully developed comparative research for both SNSs and MMOGs, in particular for the subject of bots.

## References

Becker, H. (1963). *Outsiders: Studies in the sociology of deviance*. New York: The Free Press.

Boshmaf, Y., Muslukhov, I., Beznosov, K., & Ripeanu, M. (2011, December). The socialbot network: when bots socialize for fame and money. In *Proceedings of the 27th Annual Computer Security Applications Conference* (pp. 93–102). New York: ACM.

Boshmaf, Y., Muslukhov, I., Beznosov, K., & Ripeanu, M. (2012, April). Key challenges in defending against malicious socialbots. In *Proceedings of the 5th USENIX Conference on Large-scale Exploits and Emergent Threats*, LEET (Vol. 12). Berkeley, CA: USENIX Association. Accessed March 15, 2014, from https://www.usenix.org/system/files/conference/leet12/leet12-final10.pdf

Boyd, d. m., & Ellison, N. B. (2007). Social network sites: Definition, history, and scholarship. *Journal of Computer-Mediated Communication, 13*(1), 210–230.

Braverman, H. (1974). *Labor and monopoly capital: The degradation of work in the twentieth century*. New York: Monthly Review Press.

Burke, R. H. (2013). *An introduction to criminological theory* (4th ed.). New York: Routledge.

Camisani Calzolari, M. (2012). *Analisi sui Twitter follower delle principali aziende Internazionali*. Accessed October 12, 2014, from http://web.archive.org/web/20130922210611/http://www.camisanicalzolari.com/MCC-Twitter-ITA.pdf

Castronova, E. (2005). *Synthetic worlds: The business and culture of online games*. Chicago: University of Chicago Press.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. London: Sage.

Consalvo, M. (2007). *Cheating: Gaining advantage in videogames*. Cambridge, MA: MIT Press.

Cragg, W. (1992). *The practice of punishment: Toward a theory of restorative justice*. London: Routledge.

De Paoli, S. (2013a). The automated production of reputation: Musing on bots and the future of reputation in the cyberworld. *International Review of Information Ethics* 19(07/2013). Accessed March 14, 2014, from http://www.i-r-i-e.net/inhalt/019/IRIE-Paoli.pdf

De Paoli, S. (2013b). Automatic-play and player deskilling in MMORPGs. *Game Studies*, *13*(1). Accessed March 14, 2014, from http://gamestudies.org/1301/articles/depaoli_automatic_play

De Paoli, S., & Kerr, A. (2009). "We Will Always Be One Step Ahead of Them" A case study on the economy of cheating in MMORPGs. *Journal of Virtual Worlds Research, 2*(4). Accessed March 14, 2014, from https://journals.tdl.org/jvwr/article/view/865

De Paoli, S., & Kerr, A. (2010). The assemblage of cheating: How to study cheating as imbroglio in MMORPGs. *FibreCulture Journal*, (16). Accessed October 13, 2014, from http://sixteen.fibreculturejournal.org/the-assemblage-of-cheating-how-to-study-cheating-as-imbroglio-in-mmorpgs/

De Paoli, S., & Kerr, A. (2012). On crimes and punishments in virtual worlds: bots, the failure of punishment and players as moral entrepreneurs. *Ethics and Information Technology, 14*(2), 73–87.

DeLanda, M. (1991). *War in the age of intelligent machines*. New York: Zone Books.

Elishar, A., Fire, M., Kagan, D., & Elovici, Y. (2012, December). Organizational intrusion: Organization mining using socialbots. In *Proceedings of International Conference on Social Informatics 2012* (pp. 7–12). IEEE.

Facebook. (2012). *Quarterly report—For the quarterly period ended June 30, 2012*. Accessed March 15, 2014, from http://www.sec.gov/Archives/edgar/data/1326801/000119312512325997/d371464d10q.htm

Farmer, R., & Glass, B. (2010). *Building web reputation systems*. Sebastopol, CA: O'Reilly Media.

Gartner. (2010). *Gartner reveals top predictions for IT organizations and users for 2011 and beyond*. Accessed March 15, 2014, from http://www.gartner.com/newsroom/id/1480514

Gehl, R. W. (2013). What's on your mind? Social media monopolies and noopower. *First Monday, 18*(3). Accessed March 15, 2014, from http://firstmonday.org/article/view/4618/3421

Geiger, R. S. (2011). The lives of bots. In G. Lovink & N. Tkacz (Eds.), *Critical point of view: A Wikipedia reader* (pp. 78–93). Amsterdam: Institute of Network Culture.

Heeks, R. (2009). Understanding "gold farming" and real-money trading as the intersection of real and virtual economies. *Journal of Virtual Worlds Research, 2*(4). Accessed March 15, 2014, from http://journals.tdl.org/jvwr/index.php/jvwr/article/view/868

Heidegger, M. (1927). *Being and Time* (trans: Macquarrie, J., & Robinson, E., 1962). New York: Harper.

Hwang, T., Pearce, I., & Nanis, M. (2012). Socialbots: Voices from the fronts. *Interactions, 19*(2), 38–45.

Incapsula. (2013). *Bot traffic report*. Accessed February 15, 2014, from http://www.incapsula.com/blog/bot-traffic-report-2013.html

Kerr, A., De Paoli, S., & Keatinge, M. (2014). Surveillant assemblages of governance in massively multiplayer online games: A comparative analysis. *Surveillance & Society, 12*(2), 320–336.

Kücklich, J. (2005). Precarious playbour: Modders in the digital games industry. *FibreCulture Journal, 5*. Accessed November 12, 2009 from http://journal.fibreculture.org/issue5/index.html

Latour, B. (1987). *How to write 'The Prince' for machines as well as for machination* (Online Paper). Accessed April 1, 2010, from http://www.bruno-latour.fr/sites/default/files/36-THE-PRINCE-GB.pdf

Marx, K. (1976). *The capital: A critique to political economy, volume 1* (trans: Fowkes, B.) London: Penguin.

McCaffrey, C. (2011). Four reasons why you shouldn't automate your social media marketing. *Social Media Today*. Accessed October 18, 2012, from http://socialmediatoday.com/candacemcc/379683/four-reasons-why-you-shouldnt-automate-your-social-media-marketing

McLuhan, M. (1964). *Understanding media. The extensions of man* (2001 ed.). London: Routledge.

NexGate. (2013). *The state of social media spam*. (Research Report). Accessed March 15, 2014, from http://nexgate.com/wp-content/uploads/2013/09/Nexgate-2013-State-of-Social-Media-Spam-Research-Report.pdf

PCGAMER. (2011). *Runescape bot nuking event bans 1.5 million bots in one day*. Retrieved August 8, 2012, from http://www.pcgamer.com/runescape-bot-nuking-event-bans-1-5-million-bots-in-one-day/ (Accessed 12 Oct 2014).

PCGAMER. (2012). *Diablo 3 account bans issued to "several thousand" players using bots*. Accessed March 15, 2014, from http://www.pcgamer.com/2012/12/19/diablo-3-account-bans-issued-to-several-thousand-players-using-bots/

Runescape. (2011). *Bot Busting Update Legal Proceedings*. Accessed August 8, 2012, from http://services.runescape.com/m=news/bot-busting-update-legal-proceedings

Simonite, T. (2013). *The decline of Wikipedia*. Accessed June 15, 2014, from http://www.technologyreview.com/featuredstory/520446/the-decline-of-wikipedia/

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). Accessed September 16, 2014, from https://journals.tdl.org/jvwr/index.php/jvwr/article/viewArticle/278

Sonnenreich, W. (1997). *A history of search engines*. Accessed March 20, 2014, from http://www.wiley.com/legacy/compbooks/sonnenreich/history.html

Stein, T., Chen, E., & Mangla, K. (2011). Facebook immune system. In *Proceedings of the 4th Workshop on Social Network Systems* (pp. 1–8). New York: ACM.

Sysomos. (2009). *An in-depth look at the 5% of most active users*. Accessed January 10, 2012, from https://www.sysomos.com/insidetwitter/mostactiveusers/

Taylor, T. L. (2006). *Play between worlds: Exploring online game culture*. Cambridge, MA: MIT Press.

Twitter. (2012). *Shutting down spammers*. Accessed March 20, 2014, from https://blog.twitter.com/2012/shutting-down-spammers

Wiener, N. (1988). *The human use of human beings: Cybernetics and society*. Boston: Da Capo Press.

Yee, N. (2006). The labor of fun how video games blur the boundaries of work and play. *Games and Culture, 1*(1), 68–71.

# United States Taxation of Virtual World Economies: A Review of the Current Status

**Jamie S. Switzer and Ralph V. Switzer**

The taxation of virtual world economies is uncharted terrain, one that both researchers and government officials are just beginning to scrutinize. Taxes are inevitable in any economy, but what about the increasingly lucrative virtual world economies? The market for virtual goods and services in the U.S. alone is estimated to be between $2.9 and $3.5 billion annually (Gatto, 2012; Plumer, 2012) and is predicted to grow to $5 billion by 2016 (Juniper Research, 2011). So it is no wonder that governments are beginning to take notice. Experts are divided as to the feasibility of taxation of virtual economies. Most experts agree however that there is significant ambiguity in the current U.S. Internal Revenue Code with respect to virtual worlds. It is unclear if transactions occurring in a virtual world are taxable in the U.S., and the Internal Revenue Service has to date not offered any strong guidance regarding the issue. In this chapter, we argue that virtual transactions are already subject to taxation under current U.S. law, at any point in time that the U.S. Internal Revenue Service should decide to enforce the current law, whether taking place in game worlds or unscripted worlds. This would include virtual-to-virtual transactions as well as virtual-to-real transactions, as the issue at hand is whether or not virtual activity is taxable, regardless of realization, because all goods and services have a fair market value.

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## 1 Methodology

This review examines the issue using a multidisciplinary perspective, from both Internet studies and taxation research. To research relevant literature already published regarding the taxation of virtual world economies, the authors used a number of electronic databases. Because of the multidisciplinary nature of the topic (Internet studies and taxation), four diverse electronic databases were selected: Academic Search Premier, Communication and Mass Media Complete, Business Source Premier, and LexisNexus Academic. A thorough search on the topic revealed published literature ranging from complex law journal articles (the details of which, such as specific cases relating to Internet tax law, are beyond the scope of this chapter), to articles in socio-cultural journals (such as the Journal of Virtual Worlds Research), to government documents, and to the popular press. However, even though a small body of research exists, there is scant discussion of the topic in academe.

This chapter synthesizes the published literature up to the first half of 2014, from a variety of sources and perspectives, to review the existing knowledge and provide a broad overview of the topic. The authors first present a critical analysis of the current (through the first half of 2014) state of virtual economies. Next, a thorough examination of existing legal opinions regarding the taxation of income and assets generated by virtual world transactions is discussed. The authors then offer their own analysis of the topic specific to the tax laws of the United States. Lastly, a discussion of the complexity of the topic is presented.

## 2 Taxation of Virtual World Economies

As Lehdonvirta and Castronova state, "virtual economies have been a core feature of multiplayer digital spaces almost from the beginning" (2014, p. 38). The taxation of virtual world economies is uncharted terrain, one that both researchers and government officials are just beginning to scrutinize. As the old saying goes, taxes are inevitable in the "real world," but what about the increasingly lucrative virtual world economies? With a first-quarter 2010 market for virtual goods and services of US $160 million in Second Life alone (Linden Labs, 2010), it is no wonder that governments are beginning to take notice. It is critical for scholars to be aware of this emerging issue, because the way people communicate and interact in virtual worlds could be seriously impacted if there is the possibility they may be taxed. Virtual worlds may even cease to exist if forced to comply with burdensome tax laws.

The growth of virtual worlds has exploded, providing many new kinds of entrepreneurship and earning opportunities (Lehdonvirta & Ernkvist, 2011). The number of people interacting in various virtual worlds has been estimated to be 1.4 billion (Harwood, 2012). As these virtual worlds have grown and become increasingly more sophisticated, to the extent they now mirror the offline world, a whole new "virtual economy" has emerged, blurring the line between the real and virtual.

Virtual economies are comprised of the people who participate in the economy, goods, production, markets, institutions, and money (Lehdonvirta & Castronova, 2014). Participants in and members of virtual worlds such as EverQuest, World of Warcraft, and Second Life are now buying and selling virtual goods and services offline (not in-world) in exchange for real currency, a practice referred to as "real money trading" or RMT (Nardi & Kow, 2010). Because of RMT, which is the purchase of virtual items for real currency, virtual transactions have real economic value (Camp, 2007).

An unknown number of people in virtual worlds are exchanging real currency and earning a living delivering virtual goods and services, making it possible to "work in a fantasy world to pay rent in reality" (Lastowka & Hunter, 2004, p. 11). Or, as Cherry (2013) suggests, "cyber commodification," the creation of new markets for goods or services on the Internet that have not existed previously. The total value of sales of virtual goods and services globally is estimated to be US $20.9 billion in 2014 (Juniper Research, 2014). One study on the virtual currency in EverQuest found that the virtual gross national product (GNP) of the world of Norrath was US$135 million, placing it (at the time in 2001) at 77th on the list of world economies, approximately equal to the GNP of Russia (Castronova, 2001). The online interstellar space exploration game EVE claims to have a virtual economy of US$36 million a year (Chayka, 2013) and is larger than the real-world economy of Iceland, where the company that created the game (CCP Games) is based (Pellicone, 2014). CCP Games even employs an economist to oversee the "mechanics and operation of the economy" of the virtual world (Pellicone, 2014).

With virtual worlds rivaling the GNP of other countries, it is no wonder that governments are beginning to take notice of virtual economies and RMT. The estimated annual market for virtual goods and services is expected to grow to US $40 billion by 2019 (Juniper Research, 2014). The question, then, is whether the trade in virtual goods and services is taxable, because it has real-world monetary value. As Lastowka states, "the hotly debated issue concerning the taxation of virtual property interests is another instance of the state keeping an eye on property interests in virtual worlds" (2010, p. 141).

The Joint Economic Committee of the U.S. Congress (JEC), the Australian Tax Office, the United Kingdom's HM (Her Majesty's) Revenue and Customs Office, the European Commission Taxation and Customs Union, the Ministry of Commerce of the People's Republic of China, and Swedish, Norwegian, and South Korean tax authorities are all investigating the possibility of taxing income and assets from virtual economies (Hwang, 2011; Mennecke, Terando, Janvrin, & Dilla, 2007; Nuttall, 2007; Peng & Xu, 2009; Tennant, 2010; Walpole & Gray, 2010). China already taxes certain categories of RMTs (Salomon & Soudoplatoff, 2010), although the country has not disclosed how they plan to enforce collecting those taxes (Arnold, 2012). Since 2007 Linden Labs (the owners of Second Life) has been collecting a Value-Added Tax (VAT) on all European Union users of Second Life who pay Linden Labs for anything, including registering for premium accounts and purchasing from the land store (Hwang, 2011; Second Life, 2014a).

Technological advances have far outpaced current tax laws in the United States. As famed economist Milton Friedman predicted in 2000, “cyberspace is going to make it. . .much more difficult for government to collect taxes” (in Schlimgen, 2010, p. 882). The JEC defined in the first sentence of the previous paragraph announced it would undertake a study of tax issues in virtual worlds in 2006, but no study was ever delivered (JEC, 2006). The National Taxpayer Advocate’s annual report to Congress in 2008 included a section titled “The IRS Should Proactively Address Emerging Issues Such as Those Arising from ‘Virtual Worlds’” (Nellen, 2012a) on the need for established guidelines on issues related to taxation in virtual worlds (Olsen, 2008), but no guidance was ever issued. As then-senior economist for the JEC Dan Miller stated, “It will get to the point where the dollar value becomes so sizeable that the IRS would be almost negligent if it didn’t at least look into the potential of taxing these worlds” (Thompson, 2006). Or, as Castrovona puts it, “governments will probably notice. . .tax revenue, the state’s very lifeblood, will drain away as more economic activity occurs in the ephemeral jurisdictions of cyberspace” (2005, p. 244). Recently, the U.S. Internal Revenue Service (IRS) has suggested that special regulations may be needed to address the issue of taxation in virtual worlds (Lastowka, 2010).

Many of the complex legal arguments in the literature regarding the taxation of virtual world economies were published just after the release of the JEC and IRS memos, and following the National Taxpayer Advocate’s annual report to Congress (as discussed above), in 2006 and 2008 respectively. Since then, very few thorough examinations of the topic from a tax law perspective have been published. And since the topic is so complex, it appears governments, including the United States, are reluctant to approach the subject. Yet according to a 2013 report issued by the United States Government Accountability Office, the “IRS is responsible for ensuring taxpayer compliance for all economic areas, including virtual economies and currencies” (USGAO, 2013, p. 9). The report concludes that “to mitigate the risk of noncompliance from virtual currencies, the Commissioner of Internal Revenue should find relatively low-cost ways to provide information to taxpayers, such as the web statement the IRS developed on virtual economies, on the basic tax reporting requirements for transactions using virtual currencies developed and used outside virtual economies” (p. 17). In other words, the IRS needs to find a way to communicate to taxpayers that virtual world transactions are taxable as well as how to calculate the amount owed to the government.

Researchers and scholars are also beginning to examine the issue of taxation of virtual worlds. At a 2009 State of Play symposium (held in New York University Law School) entire panels were devoted issues pertaining to virtual worlds, including their economy, legal systems, governmental systems, and policy. Emory University hosted a conference on Virtual Worlds and New Realities in Commerce, Politics, and Society early in 2008 where participants discussed emerging economies of virtual worlds. In early 2011 the University of California Irvine School of Law hosted a conference titled “Governing the Magic Circle: Regulation of Virtual Worlds.” In 2012, the Helsinki Institute for Information Technology held a seminar on “gamification and virtual economy.” These are just a few examples of the burgeoning number of conferences held worldwide that address economic, legal, and regulatory issues related to virtual worlds.

## 3 Current State of Virtual Economies

The JEC defines virtual economies as “the universe of transactions that occur within an online community, such as Second Life or World of Warcraft. . .(that) include the sale of goods and services and take place entirely within virtual economies; there is no real-world or physical exchange” (JEC, 2006). In Second Life alone there were user-to-user transactions totaling over US$160 million (1 US$ equals approximately 250 “Linden” dollars, the in-world Second Life currency, which is a floating currency) in the first quarter of 2010, a 75 % increase over the previous quarter (Oyedele, 2011). One study found that more than 50 businesses in Second Life made more than US$100,000 each in 2009, with the top 25 Second Life earners making approximately $12 million combined. Linden Labs, the parent company of Second Life, maintains a Second Life Marketplace to promote the sale of content, charging sellers a 5 % commission (Roscoe, 2011). According to Linden Lab’s CEO Ebbe Altberg (appointed in February of 2014), in the 11 years since its inception, a total of $3.9 billion worth of transactions have taken place in Second Life’s marketplace (Buckley, 2014).

Another virtual world, Entropia Universe, also operates a “real cash economy” (Entropia Universe, 2014a) with a fixed rate of 10 “Project Entropia Dollar” (PED) to US$1 (Entropia Universe, 2014b). The parent company of Entropia, MindArk, even offers banking services sanctioned by the Swedish government (Bombace, 2013). Facebook launched Facebook Credits, a virtual currency used to buy virtual goods on the Facebook platform (Facebook, 2011) where Facebook users could purchase Facebook Credits with 15 different real-world currencies, including Euros, Hong Kong Dollars, Turkish Lira, and Venezuelan Bolivars. However, Facebook took a significant cut (30 %) with each Credit purchase (Gannes, 2011). The US-based chain store Target offered Facebook Credit gift cards for people to purchase to use on the Facebook platform, marking the first time Facebook had a presence in a brick-and-mortar retail store (Swartz, 2010). (Facebook has since discontinued Facebook Credits, converting instead to local currencies payments.) Amazon.com recently announced Amazon Coins, worth one cent USD, that can be used to buy apps and games for the Kindle Fire (Sparshott, 2013).

RMT is a big business, particularly in the sale of in-world currency and high-powered user accounts (Duranske, 2008). Yet not all virtual worlds permit RMT. Second Life allows the exchange of currency, goods, and services. Second Life even has an internal system where users can exchange Linden dollars for real currency. However, the MMOGs (Massively Multiplayer Online Games) World of Warcraft, EverQuest, and Ultima Online specifically forbid the buying and selling of “gold” (their in-world currency) or items for real money (Duranske, 2008); such activity is against the terms of service or end-user licensing agreements. eBay banned auctions for property from virtual worlds such as characters, currency, weapons, and clothing in early 2007. Blizzard entertainment created an in-game player-to-player market-place for their role-playing game Diablo III, only to close it two years later because it upset the balance of the gameplay (Moore, 2013).

There is ample evidence, however, that people are making a living buying and selling virtual goods. Or, as one IRS agent stated, "selling intangibles in an intangible world. *For* an intangible world" (Dibble, 2006, p. 304). There are a number of occupations that members of Second Life make their livings from in-world, including jewelry maker, tour guide, musician, landscaper, nightclub owner, and attorney (Duranske, 2008). There are also third-party auction sites that broker in-world currency, virtual items and even entire in-world accounts. One person, Ailin Graef (whose avatar in Second Life is named Anshe Chung) claims to have achieved a net worth exceeding US$1 million from profits earned in virtual worlds, primarily through real estate transactions and content creation in Second Life (Duranske, 2008). In 2010, a player in Entropia sold a virtual resort for $650,000 (Chiang, 2010). Before Blizzard shut down their Diablo marketplace, one player claimed to be averaging US$1500 per week in the game (Evangelho, 2012).

On a more sinister note, unsavory types may also be using virtual world transactions to launder money because the transactions are virtually untraceable and can be converted into real currency (Bombace, 2013; Stokes, 2012). One rumor concerns a drug dealer in Second Life who only accepts Linden dollars as payment and then realizes a profit after converting the Linden dollars to USD (Burns, 2010). Other criminal activity occurring in virtual worlds includes identity theft, hacking, and credit card fraud (Chung, 2008). A study by Dilla, Harrision, Mennecke, and Janvrin (2013) details 20 cases of virtual world fraud, where virtual world participants were exposed to real asset loss from fraud. Gold farming, where companies (usually in low wage economies) employ people to do nothing but play MMOGs in deplorable conditions to acquire in-world currency or property which is then resold for a profit, is also driving RMT (Kennedy, 2009).

Julian Dibbell famously wrote about his attempt to make a living selling "make-believe commodities" in his book "Play Money, or How I Quit My Day Job and Made Millions Trading Virtual Loot"; in one year he made US$11,000 (Dibble, 2006). But he was stymied when he called the IRS about the status of his online assets. After putting him on "hold" for 15 min, they were ultimately unable to provide him with any guidance as how to report the income (Thompson, 2006). According to the Taxpayer Advocate, the IRS is still "unable to respond to taxpayer inquiries about how to report transactions" in virtual worlds (Benson, 2009, p. 817).

## 4 Taxation of Virtual Worlds

The IRS does not have a policy that specifically addresses taxation of income earned within virtual world economies; the growth of those economies has clearly outpaced current tax law. As Nellen (2012b) states, "the Internet has created some new types of assets that may not fall squarely within existing tax rules." While it is possible that some people do report the amount they earned in RMT it is more likely that virtual worlds are a tax haven for those who make their living buying and selling virtual goods and services. A virtual good or service can be marketed, distributed, paid for, and delivered electronically without the need for any face-to-face contact (Schlimgen, 2010). While most tax scholars believe it is a matter of "when" and not "if," researchers differ in defining exactly how the IRS would implement and enforce a law designed to tax transactions that occur in virtual worlds (Beekman, 2010). Additionally, issues regarding taxation in virtual worlds closely interact with other areas of real-world law such as property, equity, and contract law (Walpole & Gray, 2010), further complicating the matter. The academic discussion surrounding the taxation of virtual worlds revolves around three ways to approach the topic: taxing real-money transactions, identifying the difference between game worlds and scripted worlds, and the responsibilities of the virtual world operators.

Where and how the IRS, and states within the U.S., could tax transactions in the virtual world is a complex issue related to the methods currently used by these taxing authorities, although current methods could logically apply. The U.S. federal system requires the tax liability for income taxes to be correctly self-assessed by taxpayers (Assessment Authority, 26 USC 6201 (a) (1)). This requirement gives the taxing authority a significant hindsight advantage in evaluating appropriate tax liability after the filing of the tax return by the taxpayer.

Although federal and state tax authorities provide the forms that are required to be used for the tax returns, the burden of filing the required tax returns accurately is the responsibility of the taxpayer. The most common forms provided by the IRS are the Form 1040 series that are required for individuals, the Form 1065 series for non-taxpaying entities, such as partnerships and some limited liability companies, and the Form 1120 series for regular corporations and S-type corporations.

The U.S. is unique in that at the federal level it taxes the worldwide income of citizens and nonresident citizens regardless of the origin or source (IRS Publication 17, 2013). Most states also impose this wide-reaching obligation. Not all states have an income tax for individuals or business entities but those that do usually tax all income of state chartered corporations in the state and individuals considered domiciled in the state. Individuals and businesses are subject to income tax in a state only if they are considered to be conducting business in the state, although this could include virtual business or electronic business.

### *4.1 Taxing RMTs*

Mennecke et al. (2007) argue for a system that only taxes income generated when the seller converts virtual profits into real-world currency. In order to ensure that virtual economies continue to thrive, even though they would be taxed, they recommend the IRS maintain a "hands-off" policy but clearly communicate the guidelines and require the companies that maintain virtual worlds (for example, Linden Labs owns Second Life; World of Warcraft is owned by Blizzard Entertainment) convey to buyers and sellers information regarding both the law and the consequences of breaking it. In a follow-up article, the authors concluded that

"…virtual asset exchanges constitute income realization events for (Federal income tax) purposes because they involve arms-length exchanges of virtual properties that possess distinct legal and economic entitlements that are capable of being objectively valued" (Terrando, Mennecke, Dilla, & Janvrin, 2008, p. 99).

Chung (2008) suggests since virtual currencies act in many ways like "real money" and are increasingly used in the real world, they "represent cash equivalents and should be treated and taxed like foreign currency" (p. 140) at the time the currency is converted (cashed out) and an economic gain is achieved. He uses the example of the "QQ coin," a virtual currency created by the Chinese company Tencent that allow users to shop in the company's virtual world and instant messaging service. (The use of credit cards is not yet commonplace in China.) The use of QQ coins quickly grew beyond the Tencent services, with shoppers using them to purchase real-world goods and services. QQ coins are so popular that the Chinese government is pressuring Tencent to limit the trade of QQ coins because of the potential for money laundering and the inflation of the real Chinese currency, the Yuan (Chung, 2008, pp. 144–145), and is "on the lookout for any assault by such virtual currencies on the real economic and financial order" (in Castronova, 2010, p. 4).

## 4.2 *Game Worlds Versus Unscripted Worlds*

Lederman (2007, 2009) believes that not all virtual worlds should be treated equally when it comes to RMT. She makes a distinction between "game worlds" or "scripted worlds" such as World of Warcraft and "unscripted worlds" such as Second Life, arguing that transactions in game worlds should not be taxed until the seller engages in RMT but that in unscripted virtual worlds, in-world sale of virtual goods and services using virtual currency be taxed even if the transaction stays in-world and the seller does not "cash out" (engage in RMT). Her rationale for distinguishing between different virtual worlds is that "game worlds typically focus on conquering challenges, not on commerce" whereas an unscripted world such as Second Life "encourages its participants to make creations and sell copies of them and facilitates those activities" (2007, pp. 1670–1671).

Seto (2008) also distinguishes between two different types of virtual worlds: platforms with non-redeemable, non-convertible currencies such as World of Warcraft, and platforms with redeemable or convertible currencies such as Second Life. He argues that virtual world transactions in the first type of platform should not be taxed; however, if RMT occurs (even though it is against the terms of service), that transaction generates taxable income. In the second type of platform, Seto believes all transactions should be taxed; RMTs trigger a change in net worth and are therefore taxable.

Cohn (2013) categorizes virtual worlds as "closed-flow" or "open-flow." In a closed-flow system, transactions hold no value outside of the virtual world. The virtual currency can only be used to purchase goods or services within the virtual world; the income derived is not taxable. In an open-flow system, however, receiving virtual currency (such as Linden dollars) as payment for real goods or services may produce taxable income since the transaction could be exchanged for government-issued currency (USD, GBP, etc.).

### *4.3 Virtual World Operators*

Castronova (2004) puts the burden on the operator of the virtual world platform. He argues that if a virtual world operator allows virtual transactions to occur, the terms of service should reflect that the platform is intended for economic exchange and the transactions will be taxed. If the virtual world operator does not want transactions to be taxable, the terms of service must forbid RMT and the rule strictly enforced.

Mack (2008) puts the entire burden of tax collection on the operator of the virtual world platform. He argues for a "sales-and-use" tax. In this scenario, a system would be in place within the virtual world to automatically deduct a percentage of each transaction. The operator of the virtual world platform would then hold that deduction and forward it on for governmental collection.

Walpole and Gray (2010) conclude that taxation in a virtual world is based on the relevant contractual arrangements with the virtual world operators. With respect to virtual transactions, they argue that "many taxation outcomes from such activities significantly depend on property rights being established within the particular virtual world" (2010, p. 39).

Goncalves (2010) also argues that the approach to virtual world taxation lies in the legal strength of the EULA (End-User Licensing Agreement) and its interpretation. Since virtual world participants are in different countries with different jurisdictions, the interpretation of any given EULA will most likely be distinctive depending upon the jurisdiction of the user's home country.

## 5 Existing U.S. Tax Laws

Chodorow (2008) approaches the issue of taxation of virtual income within the context of the existing U.S. tax laws. The "ability to pay" is a core tax concept. Under that standard he argues that the taxation of virtual income should be based on a taxpayer's ability to cash out; if a virtual world allows participants to cash out then that income should be taxed. Likewise, virtual income earned in worlds that prohibit cashing out should not be taxed; the ability to pay real-world taxes is not a function of virtual income. Chodorow maintains that once it has been established that the virtual income has value and the participants can cash out, "the virtual nature of the income does not warrant tax treatment different from that which would apply to real-world transactions" (p. 698). In a subsequent article, Chodorow concludes that “the nature of virtual worlds warrants a hybrid approach, where the basis in individual virtual goods is separately tracked, but the basis in fungible currency is pooled and averaged” (2010, p. 283).

Camp (2007) says that while virtual economies have not considered current tax laws, there are some existing laws that do apply. For example, Section 61 of the U.S. Internal Revenue Code (IRC) clearly states that all income from whatever source derived, including the Internet, is taxable. He argues that activities and/or transactions solely in-world (which he calls “units of play”) should not be taxed unless those units are converted into cash. When people whose in-world assets become more like a medium of exchange, producing income and less like units of play, those transactions should be taxed. He also warns that the IRS could more easily make the case for taxing the income of people in virtual worlds who have more control over their virtual assets (versus the company that maintains the virtual world owning the virtual assets).

Beekman argues that there is “no good conceptual justification for treating virtual world activity differently from real world activity for tax purposes” (2010, p. 154). However, she also contends that it would be impossible for the IRS to administrate and enforce taxation in a virtual world. For one thing, the agency would have to rely on self-reporting by the taxpayer, which is problematic. Another issue is the huge administrative burden that would be placed on the IRS. While administrative concerns should not be the deciding factor in the debate on taxation in virtual worlds, the IRS regularly makes “decisions based on administrability alone, even when the result is conceptually incorrect” (Beekman, 2010, p. 173). Roscoe (2011) concurs, stating “the IRS chooses what to tax and how to tax for reasons that are not as intellectually true as authors of law review articles may prefer” (p. 21).

Experts are divided as to the feasibility of taxation of virtual economies. The academic debate centers on whether “laws” in a virtual world should be distinct from real-world laws, or that real-world laws should also be applicable in virtual worlds (Chambers, 2012). The positions reviewed above range from exempting all in-world activity from taxation, to taxing in-world activity under certain conditions such as RMTs, to taxing all in-world transactions. Revamping the U.S. Internal Revenue Code (IRC) to specifically cite virtual worlds is another option. Most experts agree however that there is significant ambiguity in the current U.S. IRC with respect to virtual worlds (Beekman, 2010; Schlimgen, 2010).

In this chapter, we argue that virtual transactions are already subject to taxation under current U.S. law, at any point in time that the IRS should decide to enforce the current law, whether taking place in game worlds or unscripted worlds. This would include virtual-to-virtual transactions as well as virtual-to-real transactions, as the issue at hand is whether or not virtual activity is taxable, regardless of realization, because all goods and services have a fair market value.

Online gambling income is already taxable under current U.S. law (even though the legality of online gambling is not exactly clear; see Rosenberg (2009) for a discussion). In the previously mentioned Section 61 of the U.S. IRC, all income earned by U.S. citizens is taxable, which includes online gambling (McClanahan

v. United States, 1961). The same law should also apply to economic activity in virtual worlds because of the key phrase in Section 61, "gross income means all income *from whatever source derived*" (emphasis added).

Therefore, there is no need for new legislation amending the current U.S. IRC in order for the IRS to begin enforcement, given the strategic approach employed in the current U.S. IRC. This is because the strategic approach within the U.S. IRC is that taxation of income is an "all inclusive net" unless that type of income is specifically exempted. Specifically, income is "any undeniable accession to wealth, which is clearly realized by the taxpayer, over which the taxpayer has complete dominion" (Commissioner v. Glenshaw Glass, 1955). This strategy eliminates the difficulty inherent in trying to identify all methods of commerce capable of generating income, tangible or intangible, now or in the future.

To escape taxation under the U.S. IRC, virtual transactions and economies would need to be identified, defined, and specifically exempted from taxation by the U.S. Congress or the courts, something that has yet to happen and is unlikely to occur. Virtual transactions, obscure offshore tax shelters, exotic financial derivative instruments, and the like are examples of creative methods to generate income that will be caught eventually in the "all inclusive net." However, the difficulty in taxing virtual transactions lies in the fact that it is impossible for the IRS to track them; they would have to rely on self-reporting, and the majority of taxpayers are not aware that those transactions may be taxable (USGAO, 2013). Additionally, as Arnold states, "it is extremely difficult to determine a fair market value for virtual items based on the instability and fluctuations of virtual markets" (2012, p. 211). The cost of tax collection may even exceed the revenues generated (Vetter, 2008). For these reasons, the likelihood that the IRS will tax virtual world transactions in the near future is minimal at best.

If the IRS chose to enforce current U.S. tax laws, the revenue from virtual worlds would be tremendous. However, overregulation of tax laws might also "result in the immediate decline of the virtual economy, lowering its total economic value, and therefore lowering the total federal revenue expected for the regulations" (Mack, 2008, p. 761). Virtual worlds may also move to a peer-to-peer network or a country outside of the U.S. to avoid detection and identification by the government. Another, more likely, scenario would be that the tremendous growth of virtual worlds would be severely impeded, depriving scholars of a rich and vast "database" for studying how people communicate and interact in such an environment.

## 6 Conclusion

Researchers are divided as to the feasibility of taxation of virtual economies. Some tax experts say that it would be easy to argue in-game profits have real-world value even within the confines of the virtual world. Additionally, virtual world trades of virtual goods and services, as well as RMT, could also qualify as barter, which is already taxable.

Others believe the logistics of taxing virtual economies would be too complex and burdensome; systems would need to be set up to provide an annual valuation for a resident's assets in a virtual world. Still other experts believe governments would not tax a "game." Complicating that argument, however, is the fact that members of Second Life insist their virtual activity is not a game (Thompson, 2006). As Bombace states, "virtual worlds (were) shown through clear evidence to be more than just a game" (2013, p. 3). However, if Second Life and other virtual worlds are not games and therefore not entertainment, then one could make the argument that the virtual world is used to conduct business, particularly when they participate in RMT markets.

Studies have found that virtual economic behavior follows real-world patterns (Castronova et al., 2009), just as real-world behaviors are often incorporated into virtual world activities (Harrison, Mennecke, & Dilla, 2013). The amount of economic activity occurring in virtual worlds, and the huge revenues being generated, "are sure to make a real impact on real-world economies" (Huffaker, Simmons, Bakshy, & Adamic, 2010). In an era where many of those real-world economies are struggling financially, imposing a tax on virtual worlds may be an opportunity for governments to expand their tax base (Schlimgen, 2010). Conversely, the virtual worlds provide people the opportunity to evade real-world taxation with relative ease. As Pienaar and Steyn (2010) state, "even though taxpayers might think it unreasonable to tax virtual income, the possible consequences of not doing so will grow and drive tax evasion" (p. 65). While virtual worlds may present a tremendous opportunity to make a profit for tax authorities, the "new paradigm offered by virtual worlds may offset the profit potential with unknown, and possibly, untenable risk" (Hwang, 2011, p. 179). Real world penalties may cause the advantages of buying and selling in a virtual world to erode (Hoops, 2011). As Chambers (2011) states, regulation of "taxable assets and income. . .would have a benefit for the real world and causes disadvantage to the virtual world" (p. 384). Lehdonvirta and Castonova put it bluntly: "real-world regulators should typically keep their hands off markets inside virtual economies" (2014, p. 118).

Real-world corporations as diverse as Nike, Time Warner, Sony, Mercedes Benz, Reuters and Sears initially created a presence in Second Life, but the majority of them have pulled out because consumers did not connect with the brands in a virtual world setting (Barnes, 2010); virtual worlds were created for recreational purposes, not business applications (Bateman, Pike, Berente, & Hansen, 2012). However, as more and more people join virtual worlds and individuals (as opposed to multinational corporations) create locations to sell their wares, the issue of taxing income and capital gains in virtual economies will only become more critical. When people begin to use Linden dollars to purchase goods or services from real-world, brick-and-mortar entities, the issue of taxation will become extremely complicated and paramount in terms of current tax laws. Jones (2009) believes that the IRS will begin to take more notice of virtual world transactions if and when one of three events occurs: courts granting property rights to virtual world participants in the virtual items they amass; vendors begin accepting virtual items on a regular basis in exchange for real good and services; or Congress adopts legislation requiring owners of virtual worlds to report certain transactions to the IRS.

Taxation of virtual world economies is an incredibly complicated topic, one that varies according to the tax code of individual countries. Scholars have presented differing opinions on the subject, and governments have provided little to no guidance as to the taxation of virtual worlds. In this chapter, the authors have synthesized the existing literature and presented a variety of arguments both for and against the taxation of virtual world economies, as well as arguments for the revision of the U.S. IRC with respect to virtual world transactions. The authors have offered their own opinion on the subject: income from virtual worlds is indeed taxable under current U.S. law; thus, there is no need to revise the law, or to disregard the law completely when it comes to the taxation of virtual world economies. However, the IRS must take action to ensure the law is comprehensible to any reasonable person likely to engage in virtual world commerce.

The 2008 National Taxpayer Annual Report to Congress (2008) stated:

> If the tax experts at the IRS cannot figure out what the rules are or should be, unsophisticated taxpayers who participate in the virtual economy have little hope of doing so. The IRS could at least make an administrative pronouncement about how taxpayers should treat these transactions in the interim as it studies the issue and the state law rules evolve. (p. 225)

Likewise, the 2013 report issued by the United States Government Accountability Office called for the IRS to address the tax compliance risks of virtual transactions and provide guidance to taxpayers on the tax consequences of virtual world transactions (USGAO, 2013). In May of 2014, the IRS issued a brief statement titled "Tax Consequences of Virtual World Transactions" (IRS, 2014) that provided very little information. In the statement, the IRS indicated that economic activity in virtual worlds is equal to "the tax treatment of bartering, gambling, business and hobby income" (IRS, 2014), the argument we have specified in this chapter. However, as discussed previously, relying on people to self-report income, and the feasibility of actually collecting taxes from economic activity in virtual worlds, is debatable. Second Life has an FAQ page regarding required tax documentation (form W-9 for US residents, form W-8BEN for non-US residents) when transaction thresholds are reached (Second Life, 2014b), but it is unknown if information regarding transactions is actually submitted.

Virtual world economies are only going to grow larger, as well as the increasing amount of money involved in those transactions. Additionally, the introduction of digital currencies such as Bitcoin (which is not backed by any government and exists only virtually) will further complicate the issue. Additional research is needed to determine the impact of digital currencies on virtual world transactions; issues of money laundering and the more unsavory aspects of real money trading such as fraud, identity theft, and gold farming also need to be examined in more detail by scholars. In practice, governments must begin to clarify their stance on taxation of virtual world transactions. Currently there is little agreement on how to analyze and classify virtual property and RMT in the US as well as internationally (Druckman-Church, 2013).

Given the disagreement among scholars and experts, and the unclear status of virtual worlds with respect to the U.S. IRC, this chapter has provided insight into the difficulties of resolving the conflict as well as the potential impacts upon virtual world economies. The authors suggest that scholars and government entities (such as the IRS) alike attempt to present definitive guidelines regarding the taxation of virtual world economies based on existing laws, and enforce those laws. In doing such, the vitality and vibrancy of virtual world economies should also be preserved and protected, as virtual worlds are increasingly integral to how society functions. It is, however, a daunting task.

## References


Arnold, W. E. (2012). Tax enforcement in virtual worlds: Virtually impossible? *Syracuse Journal of International Law & Commerce, 40*(1), 187–216.

Assessment Authority, 26 USC 6201(a) (1).

Barnes, S. (2010). Virtual worlds come of age. *Journal of Virtual Worlds Research, 3*(3)

Bateman, P. J., Pike, J. C., Berente, N., & Hansen, S. (2012). Time for a post mortem? Business professionals' perspectives on the disillusionment of virtual worlds. *Journal of Virtual Worlds Research, 5*(3), 1–15.

Beekman, N. A. (2010). Virtual assets, real tax: The capital gains/ordinary income distinction in virtual worlds. *The Columbia Science and Technology Law Review, 11*, 152–175.

Benson, C. (2009). Virtual worlds are virtually taxing. *CQ Weekly, 67*(15), 817.

Bombace, M. (2013). Blazing trails: A new way forward for virtual currencies and money laundering. *Journal of Virtual Worlds Research, 6*(3), 1–14.

Buckley, S. (2014, June 27). Second Life's second act will be a social network for virtual reality. *Engadget*. Retrieved from http://www.engadget.com/2014/06/27/second-life-social-network-for-virtual-reality/

Burns, B. (2010). Do virtual world activities give rise to real Canadian tax liabilities? *Asper Review of International Business and Trade Law, 10*, 163–185.

Camp, B. T. (2007). The play's the thing: A theory of taxing virtual worlds. *Hastings Law Journal, 58*(1), 1–72.

Castronova, E. (2001). Virtual worlds: A first-hand account of market and society on the cyberian frontier. *The Gruter Institute Working Papers on Law, Economics, and Evolutionary Biology, 2* (1).

Castronova, E. (2004). The right to play. *NY Law School Review, 49*(1), 185–210.

Castronova, E. (2005). *Synthetic worlds: The business and culture of online games*. Chicago: University of Chicago Press.

Castronova, E. (2010). On money and magic. *Journal of Virtual Worlds Research, 2*(4), 4–6.

Castronova, E., Williams, D., Shen, C., Ratan, R., Xiong, L., Huang, Y., et al. (2009). As real as real? Macroeconomic behavior in a large-scale virtual world. *New Media and Society, 11*(5), 685–707.

Chambers, C. (2011). How virtual are virtual economies? An exploration into the legal, social and economic nature of virtual world economies. *Computer Law & Security Review, 27*(4), 377–384.

Chambers, C. (2012). Can you ever regulate the virtual world against economic crime? *Journal of International Commercial Law and Technology, 7*(4), 339–349.

Chayka, K. (2013). The very real value of gaming's virtual economies. *Pacific Standard: The Science of Society*. Retrieved from http://www.psmag.com/navigation/business-economics/the-real-value-of-virtual-economies-eve-world-of-warcraft-64593/

Cherry, M. A. (2013). Cyber commodification. *Maryland Law Review, 72*(2), 380–451.
Chiang, O. (2010). Meet the man who just made a half million from the sale of virtual property. *Forbes*. Retrieved from http://www.forbes.com/sites/oliverchiang/2010/11/13/meet-the-man-who-just-made-a-cool-half-million-from-the-sale-of-virtual-property/
Chodorow, A. S. (2008). Ability to pay and the taxation of virtual income. *Tennessee Law Review, 75*(4), 695–752.
Chodorow, A. S. (2010). Tracing basis through virtual spaces. *Cornell Law Review, 95*, 283–328.
Chung, S. S. (2008). Real taxation of virtual commerce. *Virginia Tax Review, 28*(3). Retrieved from http://ssrn.com/abstract=1097793
Cohn, M. (2013). *IRS could begin taxing Bitcoin and other virtual currencies*. Retrieved from http://www.accountingtoday.com/news/IRS-Taxing-Bitcoin-Virtual-Currencies-67128-1.html
Commissioner v. Glenshaw Glass. (1955). 348 U.S. 426, 1955.
Dibble, J. (2006). *Play money: Or, how I quit my day job and made millions trading virtual loot*. New York: Basic Books.
Dilla, W., Harrison, A., Mennecke, B., & Janvrin, D. (2013). The assets are virtual but the behavior is real: An analysis of fraud in virtual worlds and its implications for the real world. *Journal of Information Systems, 27*(2), 131–158. doi:http://dx.doi.org/10.2308/isys-50571.
Druckman-Church, M. (2013). Taxing a galaxy far, far away: How virtual property challenges international tax systems. *Columbia Journal of Transnational Law, 51*(2).
Duranske, B. T. (2008). *Virtual law: Navigating the legal landscape of virtual worlds*. Chicago: American Bar Association.
Entropia Universe. (2014a). Retrieved from http://www.entropiauniverse.com/
Entropia Universe. (2014b). Retrieved from https://account.entropiauniverse.com/account/deposits/
Evangelho, J. (2012). Diablo III enthusiast nets $10K, offers insights into virtual economies. *Forbes*. Retrieved from http://www.forbes.com/sites/jasonevangelho/2012/08/08/diablo-iii-enthusiast-nets-10k-offers-insights-into-virtual-economies/
Facebook. (2011). *About Facebook credits*. Retrieved from http://www.facebook.com/help/new/?page=1038
Gannes, L. (2011). More on Facebook deals: Will include only social experiences, may use credits. *All Things D*. Retrieved from http://allthingsd.com/20110324/more-on-facebook-deals-will-only-include-social-experiences-may-use-credits/
Gatto, J. G. (2012). Virtual goods, gaming and the trouble with secondary markets. *World Online Gambling Law Report*. Retrieved from http://www.pillsburylaw.com/publications/virtual-goods-gaming-and-the-trouble-with-secondary-markets
Goncalves, D. T. (2010). Taxation of virtual worlds: An approach to face virtual worlds as electronic commerce. In I. Portela & M. Cruz-Cunha (Eds.), *Information communication technology law, protection and access rights: Global approaches and issues* (pp. 99–120). Hershey, PA: Information Science Reference.
Harrison, A., Mennecke, B., & Dilla, W. (2013). Social norms, regulatory policies, and virtual behavior. In R. Teigland & D. Power (Eds.), *The immersive internet: Reflections on the entangling of the virtual with society, politics and the economy* (pp. 214–227). Hampshire: Palgrave Macmillan.
Harwood, T. (2012). Emergence of gamified commerce: Turning virtual to real. *Journal of Electronic Commerce in Organizations, 10*(2), 16–39.
Hoops, D. S. (2011). Legal issues in the virtual world and e-commerce. In B. Ciaramitaro (Ed.), *Virtual worlds and e-commerce: Technologies and applications for building customer relationships* (pp. 186–204). Hershey, PA: Business Science Reference.
Huffaker, D. A., Simmons, M., Bakshy, E., & Adamic, L. A. (2010). Seller activity in a virtual marketplace. *First Monday, 15*(7). Retrieved from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/2977/2569
Hwang, L. (2011). Virtual market economies and the business of virtual worlds. In B. Ciaramitaro (Ed.), *Virtual worlds and e-commerce: Technologies and applications for building customer relationships* (pp. 160–185). Hershey, PA: Business Science Reference.

IRS. (2013). *Your federal income tax*. Retrieved from http://www.irs.gov/publications/p17/
IRS. (2014). *Tax consequences of virtual world transactions*. Retrieved from http://www.irs.gov/Businesses/Small-Businesses-&-Self-Employed/Tax-Consequences-of-Virtual-World-Transactions
JEC. (2006). *Virtual economies need clarification, not more taxes*. Press release #109-98. Retrieved from http://jec.senate.gov/republicans/public/?a=Files.Serve&File_id=08e6fa84-ee4f-4267-9f47-ad0ad33a072d
Jones, A. (2009). Why the IRS has not taxed income from virtual world transactions...yet. *Yale Law Journal, 118*(Pt. 142).
Juniper Research. (2011). *Virtual goods: Real revenues on mobile*. Retrieved from http://www.juniperresearch.com/whitepapers/Virtual_Goods_Real_Revenues_on_Mobile
Juniper Research. (2014). *Mobile and handheld devices: Discover, monetize, advertise 2014–2019*. Retrieved from http://www.juniperresearch.com/shop/products/report/pdf/forecasts/2075MHG14%20_LOF.pdf
Kennedy, R. (2009). Law in virtual worlds. *Journal of Internet Law, 12*(10), 3–10.
Lastowka, F. G. (2010). *Virtual justice: The new laws of online worlds*. New Haven, CT: Yale University Press.
Lastowka, F. G., & Hunter, D. (2004). The laws of the virtual worlds. *California Law Review, 92*(1), 3–71.
Lederman, L. (2007). "Stranger than fiction": Taxing virtual worlds. *New York University Law Review, 82*, 1620–1672.
Lederman, L. (2009). EBay's Second Life: When should virtual earnings bear real taxes? *118 Yale L.J. Pocket Part 136*. Retrieved from http://thepocketpart.org/2008/01/26/lederman.html
Lehdonvirta, V., & Castronova, E. (2014). *Virtual economies*. Cambridge, MA: MIT Press.
Lehdonvirta, V., & Ernkvist, M. (2011). *Knowledge map of the virtual economy: Converting the virtual economy into development potential*. Retrieved from http://www.infodev.org/infodev-files/resource/InfodevDocuments_1056.pdf
Linden Labs. (2010). *Second Life economy hits new all-time high in Q1 2010*. Retrieved from http://community.secondlife.com/t5/Features/Second-Life-Economy-Hits-New-All-Time-High-in-Q1-2010/ba-p/657582
Mack, D. (2008). iTax: An analysis of the laws and policies behind the taxation of property transactions in a virtual world. *Administrative Law Review, 60*(3), 749.
McClanahan v. United States. (1961). 292 F.2d 630, 631-632, 1961.
Mennecke, B. E., Terando, W. D., Janvrin, D. J., & Dilla, W. N. (2007). It's just a game, or is it? Real money, real income, and real taxes in virtual worlds. *Communications of the Association for Information Systems, 20*, 134–141.
Moore, B. (2013). Why Diablo's auction house went straight to hell. *Wired*. Retrieved from http://www.wired.com/2013/09/diablo-auction-house/
Nardi, B., & Kow, Y. M. (2010). Digital imaginaries: How we know what we (think we) know about Chinese gold farming. *First Monday, 15*(6–7).
National Taxpayer Advocate. (2008). *2008 annual report to Congress*. Retrieved from http://www.irs.gov/pub/tas/08_tas_arc_intro_toc_msp.pdf
Nellen, A. (2012a). Internet taxation and principles of good tax policy. *Policy & Internet, 4*(2), 1–21. Article 2. Retrieved from http://www.psocommons.org/policyandinternet/vol4/iss1/art2.
Nellen, A. (2012b). Overview of Internet taxation issues. *Bloomberg BNA Internet Law Resource Center*. Retrieved from http://www.21stcenturytaxation.com/uploads/Taxation_Overview_2012.pdf
Nuttall, G. (2007). Income earned in virtual worlds: Taxation issues. *E-Commerce Law and Policy, 9*(5).
Olsen, N. E. (2008). *Annual report to congress* (Vol. 1, Publication 2104, Rev. 12-2008). United States Department of the Treasury, Internal Revenue Service.
Oyedele, A. (2011). Customer typology: 3D virtual world. *Journal of Research in Interactive Marketing, 5*, 29–49.

Pellicone, J. (2014). Virtual economies: Gaming in the cloud is big business. *CloudTweaks: Plugging into the Cloud*. Retrieved from http://cloudtweaks.com/2014/05/virtual-economies-gaming-cloud-big-business/

Peng, H., & Xu, X. (2009, May). *Taxation in virtual world: Inevitability and feasibility*. Paper presented at the E-Business and Information System Security International Conference, Wuhan, China. doi: 10.1109/EBISS.2009.5138101.

Pienaar, S. J., & Steyn, T. L. (2010). South African income tax implications for income earned in a virtual world. *Journal of Applied Business Research, 26*(2), 47–68.

Plumer, B. (2012, September 28).The economics of video games. *The Washington Post*. Retrieved from http://www.washingtonpost.com/blogs/wonkblog/wp/2012/09/28/the-economics-of-video-games

Roscoe, E. G. (2011). Taxing virtual worlds: Can the IRS pwn you? *Pittsburgh Journal of Technology Law and Policy, XII*, 1–49.

Rosenberg, E. (2009). Online gambling poses tax conundrum. *The Wall Street Journal Market Watch*. Retrieved from http://online.wsj.com/article/SB10001424052748704779704574553763086903756.html

Salomon, M., & Soudoplatoff, S., (2010). Why virtual-world economies matter. *Journal of Virtual Worlds Research, 2*(4).

Schlimgen, J. R. (2010). Virtual world, real taxes: A sales and use tax adventure through Second Life starring Dwight Schrute. *Minnesota Journal of Law, Science & Technology, 11*(2), 877–899.

Second Life. (2014a). Retrieved from http://wiki.secondlife.com/wiki/Linden_Lab_Official:Value_Added_Tax_(VAT)_Frequently_Asked_Questions

Second Life. (2014b). Retrieved from http://community.secondlife.com/t5/Commerce/Required-Tax-Documentation/ba-p/2336109

Seto, T. P. (2008). *When is a game only a game? The taxation of virtual worlds*. Loyola-LA Legal Studies Paper No. 2008-24. Retrieved from http://ssrn.com/abstract=1220923

Sparshott, J. (2013, March 22). Web money gets laundering rules. *The Wall Street Journal*, pp. C1, C2.

Stokes, R. (2012). Virtual money laundering: The case of Bitcoin and the Linden dollar. *Information & Communications Technology Law, 21*(3), 221–236.

Swartz, J. (2010, September 1). Target to sell Facebook Credits gift cards. *USA Today*. Retrieved from http://www.usatoday.com/tech/news/2010-09-01-target01_ST_N.htm

Tennant, D. (2010). *Virtual worlds may be an escape, but maybe not from taxes*. Retrieved from http://www.itbusinessedge.com/cm/blogs/tennant/virtual-worlds-may-be-an-escape-but-maybe-not-from-taxes/?cs=41590

Terrando, W. D., Mennecke, B. E., Dilla, W. N., & Janvrin, D. J. (2008). Taxation policy in virtual worlds: Issues raised by Second Life and other unstructured games. *Journal of Legal Tax Research, 6*(1), 94–107.

Thompson, C. (2006). The virtual taxman cometh. *Wired News*. Retrieved from http://www.wired.com/gaming/gamingreviews/commentary/games/2006/12/72317

United States Government Accountability Office. (2013, May). *Virtual economies and currencies: Additional IRS guidance could reduce tax compliance risks*. GAO-13-516. Retrieved from http://www.gao.gov/products/gao-13-516

Vetter, W. V. (2008). A preliminary investigation of taxation of virtual worlds. *State Tax Notes, 47*(11), 843–860.

Walpole, M., & Gray, J. (2010). Taxing *virtually* everything: Cyberspace profits, property law and taxation liability. *Australian Tax Review, 39*(1), 39–60.

# Virtual Worlds Supporting Collaborative Creativity

**Pekka Alahuhta, Anu Sivunen, and Teemu Surakka**

## 1 Introduction

3D3C worlds can be used to support several types of activities in organizations and can be particularly powerful in fostering the creative collaboration of geographically distributed teams. We will begin our story by presenting a case study of a brainstorming session conducted in a virtual world.

This example introduces a distributed innovation activity that occurred in a 3D virtual world. Although the users were novices with regard to virtual world interaction, they were able to collaborate and contribute to a mutual goal in the novel collaboration settings. Both the attendees and the management of the case study corporation considered the output of the joint ideation to be extensive.

> An experimental case study was conducted in a Finnish pulp and paper corporation. The corporate vice president (VP) invited seven geographically distributed experts and managers with varying backgrounds and expertise to attend a meeting in a virtual world (Immersive Terf). The participants were novices in virtual world communication and did not receive any pre-training.
>
> At the beginning of the meeting, the attendees gathered in a virtual lobby. A researcher, acting as a technical instructor and facilitator, ensured that all attendees were able to operate the virtual world software. From the lobby, the participants moved to a project exhibition space to observe three virtual artefacts. The artefacts included two pulp samples that were scanned to a

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three-dimensional (3D) format and a 3D-pdf file of a mock-up object. Attendees were able to walk around the three-dimensional objects and annotate them. Moreover, the 3D-pdf file format allowed users to annotate, rotate and change the size of the object.

The corporate VP introduced the artefacts and encouraged other attendees to brainstorm possible use cases and scenarios for the artefacts. The attendees were also asked to recommend improvements that could enhance the usability of these objects. The attendees were able to express their opinions aloud or write them on electronic post-it notes near the objects. After the joint brainstorming session, the post-it notes were discussed together.

At the end of the meeting, the attendees were free to express their thoughts concerning the meeting and their first impressions of the virtual world. They were also asked to complete a post-event survey about their personal interaction in the virtual world.

Based on the example and the results of this research project, it is relevant to ask the following question: what was the role and significance of the collaboration environment in this collaborative creative activity? We answer this question first by discussing the essence of creative teamwork and then by outlining seven affordances of virtual worlds that contribute to teams' creative collaboration.

## 2 Virtual Worlds Fostering Team Creativity

Creativity is defined as the production of novel and useful ideas (Amabile, 1983). Because creativity refers to idea generation, innovation is a key component of the subsequent stages of implementing the ideas toward better procedures, practices, and products (Anderson, Potocnik, & Zhou, 2014). Therefore, creativity and innovation are closely linked (Amabile, Conti, Coon, Lazenby, & Herron, 1996) because organizational creativity can be seen as a precondition for innovation (Hennessy & Amabile, 2010).

Creativity has been explored at both the individual and the group level. At the individual level, the antecedents of creativity have been conceptualized as personality, skills, motivation, positive effect, expertise, and knowledge (Sternberg, 2006). In addition, the physical environment or the social climate can facilitate or hinder creative activities (Hunter, Bedell, & Mumford, 2007; West, 2002). Whereas the environment provides physical stimuli that may enhance individual and team creativity, the social climate includes dimensions such as goal clarity, intellectual stimulation, support for innovation and participative safety (Gibson & Gibbs, 2006).

At the group level, effective group processes are a necessary condition for converting individual creativity into group creativity (Taggar, 2002). The potential for idea generation and creativity within a team is believed to exceed the corresponding potential of individuals (Paulus & Huei-Chuan, 2000). Creative teams can collaborate locally; the attendees share a geographic location and a common physical space during the interaction. However, creative processes have become more complex and demanding in modern organizations because teams and networks are increasingly engaged in a globally distributed mode of operation. Participants in the creative process operate in separate geographic locations and time zones (e.g., Gibson & Gibbs, 2006; Ocker, 2005).

In distributed team collaboration, trust, support, freedom, challenge, goal clarity, motivation, commitment, encouragement for creativity, and sufficient resources and time are focal factors that enable creativity (Nemiro, 2002). For globally distributed teams, brainstorming activities can be challenging because team members lack a shared physical space for ideation. However, cultural diversity among team members, in conjunction with separate locations and individual expertise, may also enhance creativity during certain phases of the innovation process (Gibson & Gibbs, 2006; Kratzer, Leenders, & Van Engelen, 2006). Thus, when process losses are minimized, creative activity within distributed teams can thrive.

Distributed teams typically use a variety of communication media for their interaction. These technologies support synchronous and asynchronous modes of collaboration (e.g., Rice & Gattiker, 2001). Whereas synchronous collaboration involves real-time interaction among the collaborating participants, asynchronous interaction is not time dependent but allows participants to collaborate intermittently. Previous research (Herrmann, 2009; Preece & Shneiderman, 2009) has articulated a divergence among the suggested features that these collaboration modes require from the communication media. Both studies highlight the importance of rich and smooth collaboration and a wide range of malleable functionalities for a communication media.

Virtual worlds offer an interesting example of an emerging collaboration environment that conveys potential to distributed teams' creative co-work. Yee and Bailenson (2007) describe virtual worlds as communication systems through which multiple interactants share the same three-dimensional digital space despite occupying remote physical locations. Interactants can navigate digital space, manipulate objects, and communicate with one another via avatars that are flexible and easily transformable digital self-representations in graphic 3D form. Moreover, Bell (2008) clarifies that virtual worlds are synchronous but persistent communication systems that also enable asynchronous collaboration. Virtual worlds, already positioned at the forefront of web-based technological evolution, are likely to become more pervasive and widely adopted over time (Riordan & O'Reilly, 2011).

Psychological literature suggests that creative insights cannot be commanded to occur. However, it might be possible to create conditions using ICT that will improve the likelihood of creative discoveries, if only through the avoidance of conditions that disrupt or conflict with creativity (Hewett, 2005). Previous studies (e.g., Alahuhta, Nordbäck, Sivunen, & Surakka, 2014; Bosch-Sijtsema & Sivunen, 2013) have addressed features and affordances that (1) are typical in virtual world mediated collaboration, and (2) convey the potential to foster creative team level interaction. Using these studies as a foundation, we outline *virtual world affordances* that may foster creative team collaboration in the virtual setting. The concept of an affordance refers to an environmental property that creates consequences for individual behavior (e.g., Greeno, 1994; see also Olapirikyakul & Widmeyer, 2009). By identifying affordances that foster creative interaction in virtual worlds, we attempt to determine the essence of the creative interaction of distributed teams in general. Therefore, our research aims to pioneer a detailed scrutiny of interplay between creative processes, teamwork and technology.

## 3 Virtual Worlds' Creative Affordances

Based on our previous literature review (Alahuhta et al., 2014) and empirical research, we propose seven affordances of virtual worlds, which are related to teams' abilities to perform creative activities. The identified affordances are as follows:

1. Avatars
2. Co-presence
3. Immersion
4. Simulation capabilities
5. Dynamically changing frame of reference
6. Multimodal communication
7. Rich visual information

Notably, the affordances do not guarantee creative team performance in virtual world interaction. Instead, they are a collection of characteristics for virtual world technology that can foster creativity via the mediated behaviors and interaction practices of team members. In the following sections, we provide a description of each of the seven affordances. For each affordance, we first provide a concise definition. Then, we depict the essence of an affordance in respect to prior academic literature. We also attempt to connect the affordance to the case study example to demonstrate its manifestation within creative team interaction in virtual settings.

### *3.1 Avatars*

*Avatars are users' graphic self-representations. An avatar can be tailored to the creative task at hand. An avatar also increases a user's spatial awareness.*

Avatars are considered as individuals' digital self-representations in a graphic 3D form (Yee & Bailenson, 2007). Avatars allow users to communicate a significant amount of nonverbal social information to other collaborators (Ringo, 2007). This communication occurs both consciously and unconsciously (Antonijevic, 2008). Therefore, avatars assist users in expressing their feelings in a more convenient and accurate manner, particularly compared to other virtual community tools and collaborative environments that do not use avatars in communication (Eisenbeiss, Blechschmidt, Backhaus, & Freund, 2012).

Users show signs of self-projection with respect to avatars. In an experiment conducted by Clarke (2012), attendees demonstrated signs of emotional attachment to the avatar and also indicated an understanding of self-projection. Avatars are crucial for eliciting a sense of proximity (Larach Uribe & Cabra, 2010) and for providing spatial information (Benford et al., 1995). The spatial information and proximity contribute to turn-taking among interactants, facilitating discussion within a collaborating group. In addition, self-projection and a sense of proximity contribute to the avatar's potential to function as a self-representation of a team member in the virtual environment.

Typically, virtual world users are more or less free to tailor their self-representing avatars. This freedom allows each user to select an identity and signals that he or she seeks to express to others. Users are able to create avatars that (1) look like the actual user in real life or (2) represent something totally different (Sanchez, 2009). Arguably, the process of creating an avatar is one of the most attractive aspects of the virtual world user experience (Clarke, 2012).

The possibility for the user to *be something other than himself or herself* in an immersive collaboration environment conveys emergent potential towards creative team interaction. For instance, avatars can provide a protective shield for the user. This protective shield can ensure that the user feels comfortable and safe while collaborating as himself or herself within the virtual environment (Bosch-Sijtsema & Sivunen, 2013). Building a psychologically safe communication climate within the distributed team is important for group creativity because such a climate helps to overcome the negative effects of distributed collaboration, including geographic dispersion, when fostering creativity (Gibson & Gibbs, 2006).

Finally, the concept of avatar-based innovation (Kohler, Fueller, Matzler, & Stieger, 2011; Kohler, Fueller, Stieger, & Matzler, 2011; Kohler, Matzler, & Füller, 2009) links avatars as user self-representations with respect to open innovation (Chesbrough, 2003). Workshops in virtual worlds can harness the creativity of customers and corporate representatives via avatar representations (Giovacchini, Kohler, Teigland, & Helms, 2009). Workshop attendees can benefit from using virtual worlds as avatars, thereby enhancing the building of a psychologically safe communication climate among workshop participants. This benefit can, in turn, help to create an optimal environment for distributed group creativity.

Our own case study denoted behavior similar to that of the studies of avatar-based innovation. At the beginning of the meeting, users were trained *ad hoc* how to move the avatars in the virtual environment. The users quickly noticed that the avatars represented other users and became aware of the option to change their avatar's appearance. A typical sign of engagement that appeared via avatars was to invite another user to "*come here*" and "*look at the whiteboard*". Meanwhile, conscious gestures such as pointing at an object mediated the collaboration among interactants. Figure 1 illustrates the personified avatars gathered around a

**Fig. 1** Avatars in virtual world

shared whiteboard. One of the team members utilized a noteboard to write down key issues, which were covered during the discussion.

Overall, avatars contribute to creative team interaction by allowing team members to communicate conscious and subconscious verbal and nonverbal information to others. The team members' projections to modifiable characters can make them feel comfortable and safe, allowing the users to express their insights in a way that encourages creativity. Avatars' contribution to creativity has also been commercialized as corporations interact with customers to seek avatar-based innovations.

## 3.2 Co-presence

*The sense of co-presence is defined as a feeling of sharing a space with other collaborators. The phenomenon can foster the attendees' participation in creative interaction. Co-presence also facilitates collaboration with other like-minded virtual world users in the pursuit of shared goals.*

Co-presence can be defined as a sense of "being together" with other remote team members through the sharing of a technology-mediated environment (Biocca, Harms, & Burgoon, 2003; Ijsselsteijn, Ridder, Freeman, Avons, & Bouwhuis, 2001). Co-located team interaction involves the sharing of the interactants' physical space. During distributed interaction, team members typically occupy different physical spaces but share a common virtual space. Three-dimensional virtual worlds build on this conceptualization by attempting to reduce the distinction between physical and virtual space. By providing a shared three-dimensional place where distributed team members can interact with each other while seeing others' spatial positions and movements, the physical and virtual spaces are connected. This connection is likely to foster a sense of co-presence among virtual world users (Barrass & Barrass, 2006; Vosinakis & Koutsabasis, 2013). In other words, sharing a place and context during rich real-time interaction can foster the intensive participation of the attendees (Kohler, Fueller, Stieger, et al., 2011).

The shared place and co-presence can also contribute to more serendipitous forms of creativity. For example, the users of a virtual world can choose to enter different virtual world communities where it is possible to collaborate with other like-minded individuals and to gain inspiration from them (Riordan & O'Reilly, 2011). In these communities, the attendees initially might have weak social ties with each other and might not be closely acquainted in either real or virtual life. The mutual co-presence among the virtually connected users is expected to facilitate the exposure of diverse ideas and resources and ultimately result in enhanced creative abilities and greater innovation (Chandra & Leenders, 2012).

Our case study produced parallel results to previous studies on co-presence. In the post-event survey, six out of seven attendees agreed that they felt presence during the meeting. Figure 2 depicts a situation, within which virtual world collaborators are co-present by engaging in an intense interaction around shared whiteboards.

Similar notifications were also articulated during the interaction. For instance, one of the users encountered problems in her network connection during the meeting, causing her avatar to disappear from the virtual world. Other collaborators quickly noticed that one avatar is missing: "*Where's Jane? I can't see her!*" After seeking Jane for a while, the others continued without her. When Jane managed to rejoin the meeting, she was greeted by the other collaborators.

**Fig. 2** Embracing co-presence in virtual world interaction

Co-presence is posited to enhance interaction and knowledge sharing among the collaborators (Appel-Meulenbroek, 2010) of established teams and loosely coupled communities. The idea of co-presence, or collaboration in a shared space, is connected to team-level creativity (Chandra & Leenders, 2012; Kohler, Fueller, Matzler, et al., 2011; Kohler, Fueller, Stieger, et al., 2011; Ondrejka, 2007). We concur with these studies by identifying co-presence as one of the affordances that supports team-level creativity in virtual worlds.

## *3.3 Immersion*

*Immersion fosters persistence and interest towards teams' shared activities that occur in virtual worlds. Immersion also empowers team members' potential to adopt and use problems' context information in problem-solving situations. The perceived sense of immersion among team members can directly contribute to creative abilities.*

Immersion can be defined as the extent to which technology is capable of delivering an inclusive, extensive environment and a vivid illusion of reality to the senses of a human participant (Slater & Wilbur, 1997, p. 3). Virtual worlds provide users with three-dimensional digital spaces and the possibility of interacting in highly graphical environments. The emerging possibility also exists for highly immersive experiences that span beyond traditional ICT collaboration tools (e.g., Koutsabasis, Vosinakis, Malisova, & Paparounas, 2012; Suh & Lee, 2005).

The previously described affordance of co-presence represents the social aspects of presence: the experience of the team sharing the same virtual space. However, immersion emphasizes the user's *own* perception of his or her surroundings. Immersion is composed of physical, virtual, and image-related (i.e., the user's own perceptual interpretation of the environment) realities. The composition generates a mixed reality within which the user can become deeply immersed (Stapleton & Hughes, 2006).

Immersion is closely related to telepresence, the feeling of being present in a mediated environment in time and space (Ijsselsteijn et al., 2001). In distributed teams, the combination of immersed team members' mixed realities can result in the existence of a common virtual "co-located" space. This, in turn, may enhance the perceived co-presence at the team level. Additionally, it is posited that avatars enhance the user's immersion in the virtual environment and indicate the immersion to other team members (de Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010; Larach Uribe & Cabra, 2010).

Virtual worlds create immersive experiences for different types of situations and tasks. When users undertake an innovation-related task, their perception of a compelling experience has been recognized as a significant contributor (Kohler, Fueller, Stieger, et al., 2011). Compelling experiences lead to increased persistence and interest in further co-creation activities. Persistence and interest are considered to be an important prerequisite for creative input and promising solutions.

Additionally, engagement in a virtual co-creation was found to result in higher awareness while simultaneously fostering a desire to act on the topic being discussed (Kohler, Fueller, Stieger, et al., 2011).

An immersive experience encourages users to interact in the virtual world in a real-life manner (Larach Uribe & Cabra, 2010). Bhagwatwar, Massey, and Dennis (2013) expand this notion by demonstrating a virtual world's potential to spark creativity and to keep members immersed while performing a task. A study of co-creation in virtual worlds (Kohler, Fueller, Matzler, et al., 2011) invited users to immerse themselves in the actual problem context, to explore inspirational stimuli, and to participate in different creative challenges before submitting their ideas. The study demonstrated that by describing a particular design problem concerning the virtual world to the users within the virtual world and by achieving user immersion, the problem context was more powerful than it would have been if a simple problem description had been used.

In our case study example, virtual worlds' immersive potential was articulated in multiple ways. At the end of the meeting, users indicated verbally that multi-tasking, i.e., engaging in tasks other than the meeting was significantly difficult because of the visual appearance and rapidly changing virtual environment. The vast amount of turn-taking between speaking participants also indicates that an intense discussion occurred during the meeting. The intense discussion can be seen as an outcome of the immersion of discussion participants. In the post-event survey, users indicated that they perceived a significant level of engagement in the collaboration.

Parallel to Bhagwatwar et al. (2013), Kohler, Fueller, Matzler, et al. (2011) and Kohler, Fueller, Stieger, et al. (2011), we expect that user immersion in a virtual world will significantly contribute to a user's creative abilities. Notably, various virtual world peripherals (e.g., 3D headsets) can increase users' immersion, which could in turn enhance their creative potential. The immersed users' creative abilities are also reflected at the team level via the collaboration among team members who experience immersion. Therefore, we conclude that immersion is one of the virtual world's affordances towards creative teamwork.

## 3.4 Simulation Capabilities

*Simulation capabilities embrace the potential to tailor virtual worlds to support creative activities.*

Traditional collaboration environments embrace virtual teamwork among distant collaborators. Virtual worlds expand the possibilities of virtual teamwork with simulation capabilities. Simulation capabilities involve the emulation of physical processes, bringing the interactants closer to the notion of virtuality (Bailey, Leonardi, & Barley, 2012). Simulation capabilities are aligned with the fluency and flexibility of operations in a virtual world. For instance, virtual worlds can be used to illustrate the real-world setting in which the ideas or planned products will actually be used (Vosinakis & Koutsabasis, 2013). Conversely, learning to design and innovate in the real world can be a difficult or an expensive task, and the cost of the learning can even constrain the rate of innovation (Ondrejka, 2007).

Virtual world users can also use and manipulate two- or three-dimensional objects in the virtual environments that do not exist as physical objects in the real world. This ability can encourage virtual world users to identify and challenge some of our implicit conventions and assumptions with respect to the real world (Riordan & O'Reilly, 2011).

As an extreme, the simulation capabilities of the virtual world allow users to create entirely self-contained societies that include all the features of the human condition that exist outside the virtual world (Osborne & Schiller, 2009). Bhagwatwar et al. (2013) elaborate on this idea by investigating the virtual world's simulation capabilities through a creativity-primed and non-creativity-primed virtual world. As a result, visual elements that are known to prime creativity in real life improved the brainstorming performance of a team operating in a virtual environment. Teams produced more unique ideas that were more original, workable and relevant in the creativity-primed environment than in the non-creativity-primed environment. This finding is consistent with the premise that virtual worlds can form a context for innovative experiences within virtual customer interaction (Nambisan & Baron, 2007). The potential to enhance creative collaboration via the environment also conveys a significant potential for platform and user interface developers.

Adding to the pedagogical experiments, Tampieri (2010) used a virtual world to describe small- and middle-scale entrepreneurship in the fashion sector. The experiment participants were able to easily access and use the equipment relevant to the fashion corporation to create clothes and other fashion products. In these cases, the simulated environment assisted the experiment participants in reflecting their personal capabilities with respect to their suitability to a profession that requires creativity. Finally, an excursion to a virtual world was reported to contribute towards user ability in drawing new insights and connections with respect to existing work challenges (Larach Uribe & Cabra, 2010).

Our virtual world experiments demonstrated users' potential to use their surrounding space to guide interactions. For instance, Fig. 3 describes virtual world users dividing project tasks in a space that resembles a contemporary meeting room with tables, chairs and a shared whiteboard. When the team switches to a more creative task, the participants might move to an open, exhibition-type space that allows the parallel presentation of multiple types of content via several whiteboards and work to occur in sub-groups.

As a work platform of a distributed team, simulation capabilities allow virtual worlds to more closely substitute for reality (Bailey et al., 2012). For instance, virtual worlds can be used to inexpensively modify a learning environment for the design and investigation of new subjects (Ondrejka, 2007). This ability to modify an environment may encourage creative collaboration with unconventional methods of problem-solving (Riordan & O'Reilly, 2011). Because the simulated

**Fig. 3** Gathering around a virtual meeting room table

virtual world encourages collaborators to discover emergent and original pathways to solutions, the experience conveys a possibility to foster creative interaction.

### 3.5 Dynamically Changing Frame of Reference

*The dynamically changing frame of reference provides teams with the freedom to rapidly change and iterate their environment. Team actions are reflected in the virtual world around the team members via the transactive cycle between the team and the world.*

The affordance of dynamically changing the frame of reference expands the previously described affordance of simulation capabilities. Simulation capabilities refer to virtual worlds' potential to foster certain behavior; in addition, users are also able to change the world that surrounds them. These users' actions create a cycle of action and response that produces a transactive experience between the team and the virtual world (de Freitas et al., 2010).

Added to the possibility to alter the virtual world itself, users can also model new artefacts and alter existing ones (Vosinakis & Koutsabasis, 2013). For instance, users can multiply, scale, or move objects rapidly (Rahimian & Ibrahim, 2011). These functionalities also allow the rapid reverse-engineering of real-world objects. (Riordan & O'Reilly, 2011). When a user undertakes a change in the environment, the change alters the world for all the other users and the stimuli that other users receive from their virtual context (Merrick, Gu, & Wang, 2011).

The user-generated and modifiable virtual environments may act as engines of creation, providing users with the freedom to experiment and therefore resulting in unprecedented rates of innovation (Fuller, Muller, Hutter, Matzler, & Hautz, 2012). Typically, this potential for changing the users' frame of reference is utilized in the architectural design. Previous experiences (Merrick et al., 2011; Rosenman, Smith, Maher, Ding, & Marchant, 2007) demonstrate virtual models of planned buildings acting as context-specific virtual surroundings in design tasks. The possibility of creating virtual objects is also considered to form fertile ground for creative motivation within the virtual environment (Eisenbeiss et al., 2012). Therefore, virtual worlds may foster creativity by changing the design team's frame of reference. However, the dynamic, synchronous and evolving nature of virtual worlds also requires specific guidance with respect to the design and management of the actual process or activities that occur within these settings (Kohler, Fueller, Matzler, et al., 2011).

Experimentation with different settings and configuration elements creates an "infinite canvas" for the virtual world user (Larach Uribe & Cabra, 2010). Several studies investigate the essence and application potential of this "infinite canvas". For instance, Patera, Draper, and Naef (2008) describe how changing one's frame of reference supports the development of creative writing skills. Ketelhut, Nelson, Clarke, and Dede (2010) describe an experiment in which middle-school students were trained in creative problem-solving and scientific inquiry skills in a dynamically changing virtual world.

Within our case study experiment, the ability to change the frame of reference fostered team members' creative interaction. First, virtual world users were able to observe and annotate magnified, three-dimensional pulp samples, e.g., by zooming in on an interesting detail and attaching a text label to it. Moreover, meeting participants were encouraged to use post-it notes to express their insights on certain issues that were relevant to the meeting. Users were able to view others' post-it notes and were encouraged to build on them. During a post-experiment interview, one of the attendees noticed that in a real-life meeting room, similar behavior would not have been as successful. These examples highlight the possibilities of users expressing their insights in various ways by changing the virtual world as a context or a frame of reference.

Based on the aforementioned examples, we concur that virtual worlds' potential to change users' frame of reference from the real world and to conduct changes in the virtual world contributes to teams' creative activities.

## *3.6 Multimodal Communication*

*Multimodal communication encapsulates the virtual worlds' functionality by integrating several different communication modalities. Multimodal communication also increases the possibilities of expressing oneself in technology-mediated collaboration.*

When compared with traditional communication tools and mechanisms, current virtual worlds provide significantly richer communication methods (Bhagwatwar et al., 2013). The richness is achieved by implementing several different communication modalities through simultaneous textual, auditory, visual and graphic channels (Bosch-Sijtsema & Sivunen, 2013) or via text-based chat, voice communication, graphical cues and organizational tools (Merrick et al., 2011).

Multiple simultaneous communication channels allow spatial and communicative operations that encourage creativity that extends beyond the reach of traditional

ICT systems. As an example, virtual world users can individually explore a three-dimensional world while simultaneously communicating with fellow team members (Riordan & O'Reilly, 2011).

Multimodal communication contributes to creative collaboration by increasing the possibilities of expressing oneself in technology-mediated collaboration. The shortage of such possibilities, such as the lack of synchronous communication and feedback, can hinder the development of trust among participants (Fuller et al., 2012). Conversely, multimodal communication might increase the need for prudence with respect to technical difficulties (e.g., Berente, Hansen, Pike, & Bateman, 2011; Ferguson, 2011; Ketelhut et al., 2010).

Several empirically based studies suggest that multimodal communication within virtual worlds represents a potential virtual world affordance in creative collaboration. The combination of auditory and visual communication channels in a virtual world has been used to foster musical creativity (Barrass & Barrass, 2006). Multimodal communication within virtual worlds has also been used in distributed design collaboration (Merrick et al., 2011). Similarly, Vosinakis and Koutsabasis (2013) note the potential for virtual worlds' multimodal communication to support collaborative creativity during design studio activities.

In our example, the team of experts and decision makers used virtual worlds' potential to present multimodal information. The team observed and produced visual content. Team members engaged several times in the processing of visual contents by annotating the contents. Parallel to annotation, the team members typically talked with each other. Their speech was transmitted via audio communication channel, supporting the message that was transmitted within the visual communication channel. Finally, social cues, such as proximity among attendees, contributed to more fluent interaction.

In summary, virtual worlds combine multiple communication channels, creating a collaborative environment whose interaction qualities increasingly resemble real-life interaction. Compared to traditional communication media (such as e-mail or discussion forums), multimodal and synchronous communication encourages creative interaction in teams. Therefore, virtual worlds can generate environments that are conducive to distributed collaboration and creativity.

### *3.7 Rich Visual Information*

*Rich visual information assists in the visualization of content, i.e., models, drawings, objects and data. Rich visual information increases the awareness and understanding of different insights, ideas, and cultures. This visual information can also appeal to virtual world users.*

In addition to virtual worlds' multimodal communication channels, we highlight virtual worlds' potential to contribute to creative interaction via enhanced possibilities for presenting visual content. Existing studies (e.g., Bosch-Sijtsema & Sivunen, 2013) suggest that virtual worlds can present visual information differently than traditional communication technologies. Therefore, virtual worlds help participants to visualize models, drawings, objects, and data more effectively than traditional text and audio-based media (Riordan & O'Reilly, 2011). Virtual worlds convey the potential to present data and information in unique and compelling ways.

For example, Ringo (2007) discusses the results of a virtual world pilot at the internal IBM Innovation Jam event. In the pilot, a virtual world appealed to individuals because of its application as a visual and immersive collaboration tool. Similarly, the richness of the visual communication channels of the virtual world increases the awareness and understanding of different insights, ideas and cultures (Bosch-Sijtsema & Sivunen, 2013).

Rahimian and Ibrahim (2011) examine an experiment that monitored the differences between a traditional design environment and a 3D-immersive virtual world within a design-sketching task. The researchers note that 3D sketching resulted in a greater amount of details in sketches. Additionally, the virtual world sketching reference group had developed their ideas further than the traditional sketching group. In conclusion, virtual world technologies facilitate the conditions of collaboration during the creative design process. Finally, virtual worlds encourage out-of-the-box thinking among collaborators when the collaborators insist on using virtual tools for the construction process; the collaborators use their own ideas and adapt those ideas to the virtual tools that they are given (Sanchez, 2009).

The participants in our case study experiment extensively used virtual worlds' potential for presenting rich visual content, as illustrated in Fig. 4. During the meeting, the team observed and discussed application areas for three-dimensional samples of pulp products. In addition, a three-dimensional PDF file was co-annotated on a whiteboard. Finally, post-it notes and other conventional


**Fig. 4** A screenshot from the virtual world interaction session. 3D pulp samples are annotated with "1", the 3D PDF file "2" and avatars "3"

documentation, such as images and text, were used. The role of avatars in transferring visual information concerning the users is also embraced within the affordance of rich visual content.

Given these results, we consider the richness of the virtual world's visual communication to be an affordance related to creative interaction within the virtual world.

## 4 Discussion: Affordances Supporting Collaborative Creativity

*Our case study example of a virtual world interaction experiment was recorded, transcribed and analyzed. During the analysis, it became apparent that the interaction involved a significant amount of creative collaboration. The analysis revealed that the experiment's 449 speech turns involved more than 60 new ideas. In the survey, participants considered their performance as a team to be nearly excellent and the sessions' outcomes to be good. Notably, the interactants had neither operated a virtual world before the session nor received any training for the event.*

Creativity is often a collective effort. As technical facilities for distributed interaction develop, it is becoming feasible to engage the best available resources for teamwork, notwithstanding the limits of time or distance. In this chapter, we shed light on this development by outlining seven affordances that virtual worlds provide by supporting collaborative teamwork. These affordances suggest that virtual worlds can form nourishing contexts for creativity.

The affordances are aligned with the existing knowledge of the design principles and features that support technology-mediated design interaction. Multimodal communication, synchronous and asynchronous communication possibilities, and the assimilation of communication to the transactive cycle of action and response between the user and the environment are similar to the existing findings of communication technology-oriented design heuristics (Herrmann, 2009). Meanwhile, avatar-based interaction, co-presence, and immersion foster collaboration among users thereby supporting creative interaction (Preece & Shneiderman, 2009). We believe that the list of affordances is subject to change. This change is driven by both the technical development of three-dimensional virtual worlds and by use practices that are generated and renewed within the virtual world collaboration. Technical development, such as integrating virtual world technologies into standard web browsers, may fundamentally alter the interaction among avatars and their operations in the virtual world. Immersion and co-presence are also subject to change as new technological applications such as peripherals emerge in virtual worlds. It might also be possible to discover applications that expand virtual worlds' potential from virtual teamwork platform and simulated environment to a tool for remote-controlled operation (Bailey et al., 2012). Learning and discovering successful collaboration practices for particular teams is likely to foster the creative virtual world collaboration of a team.

Our study demonstrates the emergent potential of virtual worlds as a platform for creative collaboration. Several recommendations for practitioners can be drawn from our study. First, we suggest that practitioners extensively use the affordances and their potential that are presented in the chapter. For instance, group innovation and creativity consultants and trainers can benefit from using virtual worlds in courses and workshops because the richness of avatar-based communication in an environment that is tailored to prime creative activities has proven to foster team-level creative interaction. Using multiple communication channels can further support this interaction. Finally, simulation capabilities, including the potential to record and restore a meeting or using artificial intelligence to facilitate creative interaction, convey a potential that is relevant to virtual world practitioners engaged in creative interaction. Our findings also provide recommendations for virtual world platform and user interface designers who are interested in developing new virtual world products and services for enhancing group creativity. For example, participants' immersion could be enhanced with different virtual world peripherals, such as 3D headsets, which in turn can increase their creative potential.

Meanwhile, only a small number of studies directly address the virtual world's creative potential and few provide empirical results; the proposed affordances are therefore tentative. It is also possible that forthcoming studies discover new virtual words' affordances for creative collaboration.

Virtual worlds are gaining increasing popularity as a collaboration technology for distributed teams and organizations. In conjunction with evolving technology, it can be assumed that new industries, companies and organizations will take better advantage of the existing technology. We look forward to this development to revise our proposed list of affordances. Depending on emerging technology, changes may be fundamental.

## References


Alahuhta, P., Nordbäck, E., Sivunen, A., & Surakka, T. (2014). Fostering team creativity in virtual worlds. *Journal of Virtual Worlds Research, 7*(3), 1–22.

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357–376.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal, 39*(5), 1154–1184.

Anderson, N., Potocnik, K., & Zhou, J. (2014). Innovation and creativity in organizations: A state-of-the-science review, prospective commentary, and guiding framework. *Journal of Management, 40*(5), 1297–1333.

Antonijevic, S. (2008). From text to gesture online: A microethnographic analysis of nonverbal communication in the Second Life virtual environment. *Information, Community and Society, 11*(2), 221–238.

Appel-Meulenbroek, R. (2010). Knowledge sharing through co-presence: Added value of facilities. *Facilities, 28*(3), 189–205.

Bailey, D. E., Leonardi, P. M., & Barley, S. R. (2012). The lure of the virtual. *Organization Science, 23*(5), 1485–1504.

Barrass, S., & Barrass, T. (2006). Musical creativity in collaborative virtual environments. *Virtual Reality, 10*(2), 149–157. doi:10.1007/s10055-006-0043-5.
Bell, M. (2008). Toward a definition of “virtual worlds”. *Journal of Virtual Worlds Research, 1*(1), 1–5.
Benford, S., Bowers, J., Fahlen, L. E., Greenhalgh, C., Mariani, J., & Rodden, T. (1995). Networked virtual reality and co-operative work. *Presence-Teleoperators and Virtual Environments, 4*(4), 364–386.
Berente, N., Hansen, S., Pike, J. C., & Bateman, P. J. (2011). Arguing the value of virtual worlds: Patterns of discursive sensemaking of an innovative technology. *MIS Quarterly, 35*(3), 685–709.
Bhagwatwar, A., Massey, A., & Dennis, A. R. (2013). Creative virtual environments: Effect of supraliminal priming on team brainstorming. In *2013 46th Hawaii International Conference on System Sciences* (pp. 215–224). doi:10.1109/HICSS.2013.152.
Biocca, F., Harms, C., & Burgoon, J. K. (2003). Toward a more robust theory and measure of social presence: Review and suggested criteria. *Presence: Teleoperators & Virtual Environments, 12*(5), 456–480.
Bosch-Sijtsema, P. M., & Sivunen, A. (2013). Professional virtual worlds supporting computer-mediated communication, collaboration, and training in geographically distributed contexts. *IEEE Transactions on Professional Communication, 56*(2), 160–175.
Chandra, Y., & Leenders, M. (2012). User innovation and entrepreneurship in the virtual world: A study of Second Life residents. *Technovation, 32*(7–8), 464–476. doi:10.1016/j.technovation.2012.02.002.
Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Boston: Harvard Business Press.
Clarke, C. P. (2012). Second Life in the library: An empirical study of new users’ experiences. *Program: Electronic Library and Information Systems, 46*(2), 242–257. doi:10.1108/00330331211221864.
de Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology, 41*(1), 69–85. doi:10.1111/j.1467-8535.2009.01024.x.
Eisenbeiss, M., Blechschmidt, B., Backhaus, K., & Freund, P. A. (2012). “The (real) world is not enough:” Motivational drivers and user behavior in virtual worlds. *Journal of Interactive Marketing, 26*(1), 4–20. doi:10.1016/j.intmar.2011.06.002.
Ferguson, R. (2011). Meaningful learning and creativity in virtual worlds. *Thinking Skills and Creativity, 6*(3), 169–178. doi:10.1016/j.tsc.2011.07.001.
Fuller, J., Muller, J., Hutter, K., Matzler, K., & Hautz, J. (2012). Virtual worlds as collaborative innovation and knowledge platform. In *2012 45th Hawaii International Conference on System Sciences* (pp. 1003–1012). doi:10.1109/HICSS.2012.636.
Gibson, C. B., & Gibbs, J. L. (2006). Unpacking the concept of virtuality: The effects of geographic dispersion, electronic, dynamic structure, and national diversity on team innovation. *Administrative Science Quarterly, 51*(3), 451–495.
Giovacchini, E., Kohler, T., Teigland, R., & Helms, R. (2009). Enabling SME user-driven service innovation through virtual worlds. 9th International Entrepreneurship Forum, Istanbul, Turkey.
Greeno, J. G. (1994). Gibson’s affordances. *Psychological Review, 101*(2), 336–342.
Hennessy, B. A., & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology, 61*, 569–98.
Herrmann, T. (2009). Design heuristics for computer supported collaborative creativity. In *2009 42nd Hawaii International Conference on System Sciences* (pp. 1–10).
Hewett, T. (2005). Informing the design of computer-based environments to support creativity. *International Journal of Human-Computer Studies, 63*(1), 383–409.
Hunter, S. T., Bedell, K. E., & Mumford, M. D. (2007). Climate for creativity: A quantitative review. *Creativity Research Journal, 19*, 69–90.

Ijsselsteijn, W., Ridder, H. D., Freeman, J., Avons, S. E., & Bouwhuis, D. (2001). Effects of stereoscopic presentation, image motion, and screen size on subjective and objective corroborative measures of presence. *Presence: Teleoperators & Virtual Environments, 10*(3), 298–311.

Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology, 41*(1), 56–68. doi:10.1111/j.1467-8535.2009.01036.x.

Kohler, T., Fueller, J., Matzler, K., & Stieger, D. (2011). Co-creation in virtual worlds: The design of the user experience. *MIS Quarterly, 35*(3), 773–788.

Kohler, T., Fueller, J., Stieger, D., & Matzler, K. (2011). Avatar-based innovation: Consequences of the virtual co-creation experience. *Computers in Human Behavior, 27*(1), 160–168. doi:10.1016/j.chb.2010.07.019.

Kohler, T., Matzler, K., & Füller, J. (2009). Avatar-based innovation: Using virtual worlds for real-world innovation. *Technovation, 29*(6–7), 395–407. doi:10.1016/j.technovation.2008.11.004.

Koutsabasis, P., Vosinakis, S., Malisova, K., & Paparounas, N. (2012). On the value of virtual worlds for collaborative design. *Design Studies, 33*(4), 357–390.

Kratzer, J., Leenders, R. T. A., & Van Engelen, J. M. (2006). Team polarity and creative performance in innovation teams. *Creativity and Innovation Management, 15*(1), 96–104.

Larach Uribe, D., & Cabra, J. F. (2010). Creative problem solving in Second Life: An action research study. *Creativity and Innovation Management, 19*(2), 167–179. doi:10.1111/j.1467-8691.2010.00550.x.

Merrick, K. E., Gu, N., & Wang, X. (2011). Case studies using multiuser virtual worlds as an innovative platform for collaborative design. *Journal of Information Technology in Construction, 16*, 165–188.

Nambisan, S., & Baron, R. (2007). Interactions in virtual customer environments: Implications for product support and customer relationship management. *Journal of Interactive Marketing, 21*(2), 42–63. doi:10.1002/dir.

Nemiro, J. E. (2002). The creative process in virtual teams. *Communication Research Journal, 14*(1), 69–83.

Ocker, R. J. (2005). Influences on creativity in asynchronous virtual teams: A qualitative analysis of experimental teams. *IEEE Transactions on Professional Communication, 48*(1), 22–39.

Olapirikyakul, K., & Widmeyer, G. (2009). Affordances of virtual world commerce: Instrument development and validation. In *AMCIS 2009 Proceedings*. Paper 304. Available at: http://aisel.aisnet.org/amcis2009/304

Ondrejka, C. (2007). Collapsing geography Second Life, innovation, and the future of national power. *Innovations: Technology, Governance, Globalization, 2*(3), 27–54.

Osborne, E., & Schiller, S. (2009). Order and creativity in virtual worlds. *Journal of Virtual Worlds Research, 2*(3), 3–16.

Patera, M., Draper, S., & Naef, M. (2008). Exploring magic cottage: A virtual reality environment for stimulating children's imaginative writing. *Interactive Learning Environments, 16*(3), 245–263. doi:10.1080/10494820802114093.

Paulus, P. B., & Huei-Chuan, Y. (2000). Idea generation in groups: A basis for creativity in organizations. *Organizational Behavior and Human Decision Processes, 82*(1), 76–87.

Preece, J., & Shneiderman, B. (2009). The reader-to-leader framework: Motivating technology-mediated social participation. *AIS Transactions on Human-Computer Interaction, 1*(1), 13–32.

Rahimian, F. P., & Ibrahim, R. (2011). Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design. *Design Studies, 32*(3), 255–291. doi:10.1016/j.destud.2010.10.003.

Rice, R. E., & Gattiker, U. E. (2001). New media and organizational structuring. In F. M. Jablin & L. L. Putnam (Eds.), *The new handbook of organizational communication: Advances in theory, research, and methods* (pp. 544–581). Thousand Oaks, CA: Sage.

Ringo, T. (2007). IBM explores new frontiers in collaborative innovation. *Research Technology Management, 50*(5), 6–7.

Riordan, N. O., & O'Reilly, P. (2011). S(t)imulating creativity in decision making. *Journal of Decision Systems, 20*(3), 325–351.

Rosenman, M. A., Smith, G., Maher, M. L., Ding, L., & Marchant, D. (2007). Multidisciplinary collaborative design in virtual environments. *Automation in Construction, 16*(1), 37–44. doi:10.1016/j.autcon.2005.10.007.

Sanchez, J. (2009). Barriers to student learning in Second Life. *Library Technology Reports, 45*(2), 29–34.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and virtual environments, 6*(6), 603–616.

Stapleton, C., & Hughes, C. E. (2006). Believing is seeing: Cultivating radical media innovations. *IEEE Computer Graphics and Applications, 26*(1), 88–93.

Sternberg, R. J. (2006). The nature of creativity. *Creativity Research Journal, 18*(1), 87–98.

Suh, K., & Lee, Y. (2005). The effects of virtual reality on consumer learning: An empirical investigation. *MIS Quarterly, 29*(4), 673–697.

Taggar, S. (2002). Individual creativity and group ability to utilize individual creative resources: A multilevel model. *Academy of Management Journal, 45*(2), 315–330.

Tampieri, L. (2010). The simulation by Second Life of SMEs start up: The case of new fashion perspectives. In A. D'Atri, M. De Marco, A. M. Braccini, & F. Cabiddu (Eds.), *Management of the interconnected world* (pp. 259–266). Heidelberg: Physica.

Vosinakis, S., & Koutsabasis, P. (2013). Interaction design studio learning in virtual worlds. *Virtual Reality, 17*(1), 59–75. doi:10.1007/s10055-013-0221-1.

West, M. A. (2002). Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups. *Applied Psychology, 51*(3), 355–387.

Yee, N., & Bailenson, J. (2007). The Proteus effect: The effect of transformed self-representation on behavior. *Human Communication Research, 33*(3), 271–290.

# Virtual Currencies, Micropayments and Monetary Policy: Where Are We Coming From and Where Does the Industry Stand?

**Ruy Alberto Valdes-Benavides and Paula Lourdes Hernandez-Verme**

## 1 Introduction

We aim to assess the consequences that the use of this new kind of currencies may have for economic theory in general, and to general equilibrium models in particular. A related issue, we will cover, has to do with the standard practice of designing and implementing economic policy, especially with respect to monetary and foreign exchange policies. We consider that virtual currencies may be the beginning for the next technological shift in money as we know it (including fiat money), this should be of no surprise, after all money has been a changing technologic since its origins. The rise of these innovations comes from the new necessities that virtual worlds, online communities and electronic commerce demand to facilitate transactions between its users. In some cases, their reach has overtaken the online arenas mentioned before, for instance, virtual currencies like Bitcoin are also accepted in brick-mortar businesses. Before we go into details we should highlight that this chapter is an extended version of our previously published article in The Lantern Issue Part 2 of the Journal of Virtual Worlds Research (Valdes-Benavides & Hernandez-Verme, 2014).

It is important to highlight, as the European Central Bank (2012) report on Virtual Currency Schemes states, that there is a clear lack of reliable information about the size of the markets of virtual goods and virtual currencies. There is also a shortage in academic studies of these subjects. We therefore rely primarily on information published on the Internet. However, as this is a pioneering work in a new field, we ask the reader to bear with us patiently.

The remarkable rapidity at which technological changes are being thrown at us has made it difficult thus far to take a step back and try to understand and

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comprehend the whole picture implied by them in many dimensions: it is still difficult to grasp how our daily environment is being affected by virtual currencies; but it is even more challenging to start thinking about the consequences that virtual currencies will have in terms of the validity and the usefulness of the standard scientific methods and tools employed by macroeconomists and monetary theorists.

A particularly important repercussion has to do with the main work-horse used in macroeconomics and the equilibrium approach to macroeconomics, which is the Arrow-Debreu model of dynamic stochastic general equilibrium. As Farmer (2002, p. 1) argues:

> My main message is contained in the idea that one can think about macroeconomics as the study of equilibrium environments in which the welfare theorems, which equate competitive equilibria with Pareto optimal allocations of resources, may break down. Once one accepts this idea it becomes possible to discuss the role of government policies in a context in which policy may serve some purpose.

It follows that economic allocations should be interpreted as equilibrium outcomes that result from the interaction of different groups of actors that reach an agreement simultaneously regarding the valuation (prices) of the different goods and services that they care about. The mechanism that coordinates these decentralized individual decisions is the set of all relative prices of the economy, which may or may not adequately reflect the relative scarcity of the different goods and services. An equilibrium where relative prices are a good signal of scarcity is called efficient, and it usually arises in the absence of economic frictions or distortions.

A majority of the most interesting applications of general equilibrium deal with departures from the Arrow-Debreu model, and they may help us illustrate some important features of applied general equilibrium models. Briefly, these are: (1) macroeconomic equilibria need not be uniquely determined by the fundamentals of the economy; (2) the fundamentals or deep parameters refer to parameters that summarize preferences, technologies and resources constraints and govern individual decisions; (3) the apparently irrelevant beliefs of individuals may become self-fulfilling; (4) indeterminate equilibria may reflect the possibility that beliefs can influence aggregate market outcomes; (5) different equilibrium outcomes may be associated with alternative policy options; and (6) general equilibrium models deal with contingent commodities: we usually attach to them a particular date, a location and a state of nature. However, it is important to highlight that the departures from the Arrow-Debreu just mentioned mostly deal with physical environments where most people trade contingent commodities and where commerce takes place in traditional brick-and-mortar stores. This has been an acceptable characterization of trade until recently.

Nowadays, though, we have virtual games that create virtual realities and need virtual currencies to function, together with digital goods that are traded electronically, as opposed to the standard physical environment with traditional brick-and-mortar stores that we are used to dealing with. On top of that, we also have many kinds of electronic purses and a variety of accounts that are needed in order to transact directly or indirectly in these virtual worlds or with digital goods. Another noteworthy aspect are the quickly expanding social networks, which have created new necessities as well. Overall, we can hardly keep up with the pace of these innovations, and so we also struggle when trying to define these many newly created objects.

It is undeniable that we all feel overwhelmed and in the middle of all this over-spreading novelty. In spite of this—but possible also because of it—some of us think that the time may finally have come for us to take up the challenge of building a new class of general equilibrium models that are responsive to our ever-changing and complex reality. In particular, now is the time for monetary theorists to gradually start moving away from our standard monetary general equilibrium models, since the latter deal only with very limited kinds of currencies—either with standard commodity money or fiat money in a regular physical environment. But our new reality needs more than that: we should start thinking about virtual or digital currencies in virtual and/or digital worlds. Our Arrow-Debreu models, as they are now, are not yet ready to allow us to respond to these new needs and worlds.

Observation and relevant experts both indicate that most of the above-mentioned changes have been concentrated on the sectors of electronics and telecommunications. We propose to start building on three very simple ideas: first, that the emergence of virtual or electronic currencies is at the heart of these occurrences and that it has been the oil lubricating its workings; second, that our models cannot yet deal with all the events mentioned; and, last but not least, that this is a multi-dimensional issue.

Thus, our proposal entails a serious effort to take the general equilibrium models used by monetary economists one step forward. However, this is easier said than done, since this can be a grueling task that can lead to disappointment if it is not done sequentially, taking one small step at a time. We believe that this chapter is a first step in this direction, where we propose to undertake a particularly important first task (that may prove not to be as simple as we would like): trying to come up with an all-encompassing definition of virtual/electronic/digital currency. We are aware that we are proposing to define something that we may not understand fully as yet, but this is also the beauty of this challenge. Moreover, we will follow our own advice and will be focusing mostly on the economic and financial aspects of this phenomenon at this stage; this is to be complemented in subsequent stages of our research with the legal and institutional aspects, which are equally important but are for the moment beyond the scope of the enquiry.

There is a notion deeply ingrained in every one of us that comes up whenever we try to deal with the concept of a currency, in whatever form: one way or another, a currency is something that requires trust and a very high involvement on the part of government and related institutions. Keeping this in mind, we propose to start by mentioning these definitions as they are put in place by some official institutions. A first take on the subject is that of the Financial Service Authority of the United Kingdom, which defines electronic money as follows:

> Electronic money (e–money) is electronically (including magnetically) stored monetary value, represented by a claim on the issuer, which is issued on receipt of funds for the purpose of making payment transactions, and which is accepted by a person other than the electronic money issuer. Types of e-money include pre-paid cards and electronic pre-paid accounts for use online.
>
> Financial Services Authority.website (2013)

We must be aware that the value we assign to the goods and services we wish to consume directly or that we use to produce other goods is, most frequently, expressed in monetary units, since one of the most essential functions that a currency has to fulfil is to be a unit of account; i.e., we use the legal tender every day to value all of our transactions and the things we care about. But nowadays we must also account for a new kind of money, the use of which is expanding rapidly: one can use virtual currencies. Virtual currencies are redeemable either in fiat money or in some kind of goods, but they need not be backed by a legal tender, as a representative currency would. The value of such transactions performed over the Internet has increased enormously: goods and services that were previously purchased at "bricks-and-mortar" stores are now acquired over the Internet. Interestingly, these transactions mostly use electronic equivalents of fiat money (e.g., electronic funds transfers, debit cards or credit cards) as media of exchange. Moreover, the current forms of electronic money (including digital cash or stored value cards) have been engineered to operate in such a market.

Before getting started, we lay out what we understand to be the most important issues related to e-commerce. Among them, we highlight the definitions of micropayments, virtual currency, digital goods and virtual goods (Fig. 1).

Regarding micropayments, it must be said that the related technological advances have created a rapidly expanding market for micro-products. A micro-product is a good or service with a price below a certain arbitrary monetary amount. However, the particular value of this upper value varies widely by audience, going from 1 euro (as in Innopay) to US$12 (in PayPal). We have to pick a particular value so that the results that we present in this research are consistent and clearly bounded. Thus, we will use the definition of Burelli et al. (2011, p. 9):

> 'Micropayments' is a term that identifies transactions of low value; however the exact definition varies considerably by audience. For the purposes of this report, a micropayment is defined as 'an online or mobile, real-time or deferred, financial transaction below five euros which initiates the instantaneous delivery of a digital good'. They can be used to charge customers on a purchase-by-purchase basis for a range of digital goods, including access to news content, online music, TV shows and films.

For the purpose of comparability, we transformed the value of 5 euros into US dollars, which is roughly equivalent to $6.5. (This cipher conversion to dollars is attributed by Burelli et al. (2011) to *The Economist*.)

A couple of related definitions are those of digital goods and virtual goods. On the one hand, a digital good is defined by Webopedia as follows:

> In electronic commerce, digital good is a general term that is used to describe any goods that are stored, delivered and used in its electronic format. Digital goods are shipped electronically to the consumer through e-mail or download from the Internet. Usually

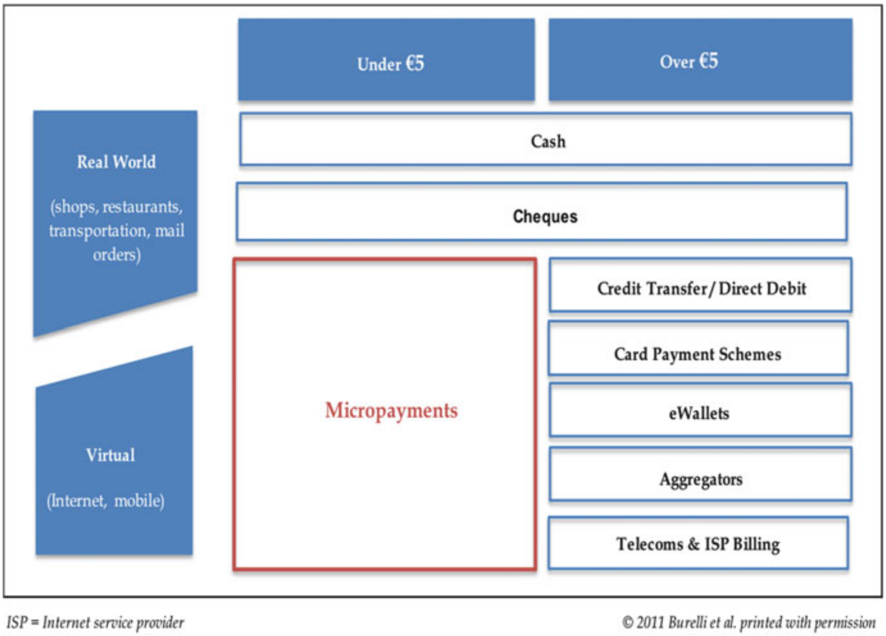


**Fig. 1** The position of micropayments in the payments landscape

> when you purchase digital goods online, after payment has been received the merchant will provide you with your digital item as an e-mail attachment or they may provide you with a secure link where you can download the item. Examples of digital goods include e-books, music files, software, digital images, Web site templates, manuals in electronic format, and any item which can be electronically stored in a file or multiple files.
>
> Webopedia.

It is crucial to clarify as well that digital goods are sometimes labeled electronic goods in the related literature. We believe that it is also important to define what a virtual good is. As stated by The Computer Language Company Inc.:

> Virtual goods are images of real things that are purchased to enhance online games and social networks. For example, players can purchase elaborate avatars to represent themselves, send an image of flowers to someone.
>
> The Computer Language Company Inc.

It is also worth defining what a virtual currency is, since this is the main object of study of this research. As before, one could find many definitions, but we believe that they all complement each other. The European Central Bank gives the following definition of virtual currency:

> A virtual currency can be defined as a type of unregulated, digital (electronic) money, which is issued and usually controlled by its developers, and used and accepted among the members of a specific virtual community.
>
> European Central Bank (2012, p. 5)

We must also complement this definition by saying a couple of other things. First, there are examples of virtual currencies the value of which is actually backed by tangible assets (as in the case of Ven). Secondly, a virtual currency can be issued either by a government or by private agents (as in most cases). An example of the former would be Mintchips: according to Boswell (2012, April), it is a currency not in use yet but that will be issued in the near future by the Canadian government to substitute the use of small change. Mintchips are intended to cover micro transactions (of a value below $10) and nano transactions (of a value below $1). As examples of virtual currencies issued by private agents, we can mention (among many) Amazon Coins and Bitcoin. As we will see below, not all virtual currencies are only accepted among the members of a specific virtual community—a few of them may also be accepted by users of other communities. See Table 4 for a more complete list of examples of virtual currencies.

The remainder of this thesis is organized a follows: Sect. 2 presents a brief review of the previous literature. Section 3 details the nature of the transactions and the institutions that deal with micropayments. In Sect. 4, we present what we consider to be the main challenges that will be faced by monetary policy and Sect. 5 concludes. Before starting we explain the methodology that we used in our research.

## 1.1 Methodology

In order to construct this chapter, we reviewed different works from various kinds of sources (academic, news, etc.). The methodology for the selection of the references was based on different criteria (see Table 1), depending on the kind of work that we wanted to include. Nevertheless, as mentioned above, since this is a fairly recent topic, there is a clear lack of related academic references and data. Thus, we had to rely on information mostly published on the Internet that, even

**Table 1** References and criteria of selection

| Number of references | Type of reference | Criteria of selection | Exceptions |
|---|---|---|---|
| 29 | Academic papers | Peer reviewed | 4 |
| 2 | Presentations | Established institution | 0 |
| 5 | Books | Established publisher | 0 |
| 2 | Reports | Established institution | 0 |
| 26 | Newspapers and magazines | Established institution | 8 |
| 11 | Blogs | Blogger from established institution | 2 |
| 2 | Others | See appendix | 0 |

Elaborated by the author

though it is from specialized sites, some may argue is not as reliable as one would wish. In Table 1 we explain what kind of references we used in our work, on which criteria we based our selection and whether there were some exceptions; a more detailed explanation may be found in the Appendix.

For example, in the first line of Table 1 we indicate that we selected 29 academic papers, and our criteria of selection was whether they were peer reviewed; in the last column we indicate that four of those papers did not fit with the requirement. For the other types of references, when we talk about established institution or publisher, we mean that they are internationally recognized and have a strict process of editing before they are published.

## 2 Review of the Previous Literature

In this section we present a brief review and classification of the previous literature, regarding private and virtual currencies, and the design of monetary policy. We divide the literature in the following sub-sections: (1) private currencies, (2) virtual worlds and virtual currencies, (3) the trust in fiat money, (4) models of electronic and private money, (5) two-sided markets, (6) monetary economies and payment systems, (7) The Suffolk baking system, (8) theoretical models of private money and (9) payments systems and electronic money.

### *2.1 Private Currencies*

*The Denationalization of Money: An Analysis of the Theory and Practice of Concurrent Currencies* (Hayek, 1978) is one of the most influential books for modern private currency schemes. In this work, the author argues that the best way to obtain an efficient monetary system is to have different privately-issued currencies that compete against each other. This way, the currencies with the more stable purchasing power would be preferred over the ones with a continuously fluctuating value. He strongly criticized the role of central banks in as much as they hold the monopoly on the creation of legal tender. He stated that monetary intervention would end up distorting interest rates at an unsustainable low rate and would eventually lead to a recession. Hayek advocated in favor of commodity-backed money, and although he was not entirely satisfied with the idea of having currencies backed with gold, he stated that in the period when he wrote his book, gold was the best known way to have a stable currency.

## 2.2 Virtual Worlds and Virtual Currencies

Edward Castronova (2001) is the pioneer in the study of the economies of virtual worlds in massively multiplayer online role-playing games (MMORPGs) from an academic perspective. He analyzed the economic activity in the virtual world "Everquest." Castronova (2003) proposes a model with a utility function that differs substantially from ordinary ones, but what an economic agent does in the model is not so different than in the real world. According to Yamaguchi (2004), in the model of Castronova (2003), avatars are like goods, and an economic agent may purchase the avatars by spending time instead of money. The utility maximization through the allocation of time to avatars is in essence the same as that through the allocation of money to goods to be consumed. Castronova (2008a, 2008b) shows the results of an experiment of a massively multiplayer online gaming called "Arden: The World of Sheakspeare." They documented that people in fantasy games act in an economically normal way, purchasing less of a product when prices are higher, all other things being equal. This finding may open the way for future studies of real economic behavior in synthetic worlds, since he gives a very good insight into how virtual worlds can be studied on the same basis as the "real" economy.

Another paper about virtual currencies is that by Irwin, Chase, Grit, and Yumerefendi (2005). They proposed a self-recharging virtual currency model as a common medium of exchange in Cereus, a computational market for community resource sharing. Self-recharging means that the purchasing power of spent credits is restored to the consumer's budget after some delaying effect; the credits recharge automatically, ensuring a stable budget but bounding the opportunity for hoarding. The purpose of the self-recharging currency is to eliminate the reliance on fragile mechanisms to recycle currency through the economy. A community admits members based on their identities; in return for the benefits of membership, members submit to accepted standards of behavior within the community. Community resource-sharing in Cereus is accountable: actions taken with a member's identity are non-repudiable, and members are subject to auditing and sanctions for misbehavior, including forfeiture of currency or ejection from the community. Similar to Castronova (2008a, 2008b), he concludes that alternative currency models can help to harness market principles as a technology for flexible, robust distributed resource allocation, enabling market-inspired systems that are simpler, more stable, more predictable, and/or more controllable than real-world economies.

In the same line of research of Edward Castronova, Salomon and Soudoplatoff (2010) give a general perspective on the importance of studying virtual world economies. They address the potential effects of these markets, as in the case of QQ coins in China. Also, they analyze some of the regulations that have been enacted regarding virtual worlds, and explain why the actual regulations will not have an important effect on the way these markets work.

Sandqvist and Zackariasson (2010) explored the relation between the dematerialization of currencies and democracy. They state that virtual currencies will have an effect in the democratization of virtual and digital worlds. Although their relation with democratization could be controversial, their analysis provides reliable information about the state-of-the-art of virtual currencies and their regulations.

The European Central Bank (2012) has provided one of the most complete surveys regarding virtual currencies so far. They analyze the rise of virtual currencies, how they work, their different kinds, their possible effects and the actions that central banks may take if they turn out to be a serious problem for price and currency stability. They also provide a specialized analysis of Bitcoin and Linden Dollars. The reader might want to be cautious, though, since the authors may take the point of view of a central bank authority and thus focus on how to regulate these currencies, how to prevent illicit activities—such as money laundering and tax evasion—together with price and financial instability, leaving aside important potential issues such as the opportunities and the wisdom that these technologies may provide, such as freedom of expenditure and the inclusion of new costumers that could not enter these markets before. Nevertheless, they do recognize that these currencies have the potential to work for hedging purposes if people lose trust in legal tender (as in the case of China’s QQ coins).

### 2.3 The Trust in Fiat Money

Bishop and Green (2012) argue that after the crisis of 2008, the trust in fiat money is under serious threat. They say that the consequences of central banks’ new tools, such as quantitative easing, are difficult to predict, so the general public is starting to raise questions regarding the soundness of fiat money and looking at alternative currencies. They mainly analyze the implications of a return to a gold standard. They claim that even though gold recently reached an all-time high value, the costs implied by a return to a gold standard would outweigh the benefits. In this spirit, the authors point out that the arguments supporting the return to gold lack consistency once one analyzes the series of historical values that gold had when it was used as a currency or to back the value of a currency. In addition, they state that gold is a low-tech currency that is likely to be substituted for other kinds of high-tech currencies. In this sense, they seem more optimistic when they talk about virtual currencies, since they believe that these new kinds of monies will be offering important innovations that central banks will have to take into account if they want to keep people believing in the stable value of fiat money. Finally, they do not discount the possibility of new kinds of currencies that will not depend on governments at all, or at least seriously competing against fiat money, in the near future.

### 2.4 Models of Electronic and Private Money

Schmitz (2008) raises a general critique of the conventional general equilibrium and money design models of electronic and private money. He concludes that the method of institutional analysis is the appropriate conceptual framework to investigate the impact of the diffusion of electronic money on the efficacy of monetary policy and the future of central banking. Moreover, he believes that existing models do not particularly take this into account. He states that the analysis of both recent and long-run institutional changes in payments systems demonstrates that their main drivers are politico-economic factors, and the demand by commercial banks and final customers, rather than technological innovations. Although he does not build a model of his own, his contribution is important because he raises the question of how much weight technological innovations have in the evolution of monetary policy.

### 2.5 Two-Sided Markets

Micropayment systems are not a simple market to study since most of them exhibit two-sided network effects. According to Rochet et al. (2006, p. 645):

> Two-sided (or more generally multi-sided) markets are roughly defined as markets in which one or several platforms enable interactions between end-users, and try to get the two (or multiple) sides "on board" by appropriately charging each side.

See-To, Jaisingh, and Tam (2007) found that the underlying dynamics of these two-sided markets are not very well understood and this may lead to mixed results of various micropayment initiatives. They concluded that a "survival mass" of merchants and consumers is required for the market to exist and a "critical mass" for the acceptance levels to take off and remain stable. The survival mass is completely determined by the normalized cost of adoption. The critical mass is higher than the survival mass due to two-sided network effects. Merchants will not adopt the system unless there are enough consumers who use it; at the same time, consumers will not consider the system until there are enough adopters on the merchants' side. Thus, the value of a micropayment system to a consumer increases as more merchants adopt the system. Similarly, the value of the system to a merchant will increase as more consumers are willing to transact with the merchant using the new electronic means. They use anecdotal evidence to reinforce their conclusions: they compare the failure of initiatives like Mondex and Visa Cash with the success of the Octopus Card in Hong Kong. The latter was originally introduced to the public in 1997, targeting a public transportation market with 10 million passenger journeys per day. The Octopus card system has been growing almost continually since its appearance; it was also intended to support non-transportation micropayment transactions because it quickly gained a critical mass. We need to take into account the fact that these authors' analysis was conducted when the new technologies that made transaction costs cheaper (like mobile payments) were not yet as developed as they are today, which could be another reason for the failure of the first initiatives like the Visa Cash and Mondex examples mentioned above.

### *2.6 Monetary Economies and Payment Systems*

Champ, Freeman, and Haslag (2011) may be of help to model monetary economics using the classical paradigm of rational agents in a market setting. As a proposal, one may add the existence of a new kind of money that resembles a virtual currency, which coexists with fiat money in a payments system like that developed by Freeman (1996a, 1996b), of an economy where fiat money serves both as a medium of exchange and the means by which debts are cleared.

### *2.7 The Suffolk Banking System*

The studies of Smith and Weber (1998) and Rolnick, Smith, and Weber (1998) on the Suffolk Banking System that existed in New England (1825–1858) are useful to compare this old private banknote issuance with the new kinds of private issuance and regulation that have arisen due to the development of electronic money and telecommunication technologies. It is crucial to take the pros and cons of the Suffolk Banking System into account when studying virtual currencies, because it is one of the most representative examples of privately-issued currency in the history of money, and it may thus influence the design of these new monies and payment systems.

### *2.8 Theoretical Models of Private Money*

Two of the most important theoretical papers dealing with the potential effects of private money are Williamson (1999) and Temzelides and Williamson (2001). They both used a random matching model of the foundations of money for economies populated with infinitely-lived agents. Among their results and recommendations, they emphasized that transaction costs, informational frictions, and related factors are the main causes explaining the discounts observed when trading different private currencies (most virtual currencies can be seen as private electronic currencies). The private money they study is a surrogate of fiat money that takes the form of a medium of exchange issued by financial intermediaries. However, according to Hernandez-Verme, Huang, and Whinston (2004a, 2004b, p. 4):

> as argued convincingly by Schreft (2001), even though the models offered by Williamson (1999) and Temzelides and Williamson (2001) are a good representation of how the financial system worked during the 19th century, they do not provide a clear insight on how a modern system of private electronic money would work and how the necessary network shall function. Moreover, these models are clearly not designed to address the problems faced in the micro-product market.

Nevertheless, Temzelides and Williamson (2001) did address the importance of re-studying private money systems. They stated that now (unlike the nineteenth century) there are much lower costs of operating private money, for two reasons: (1) fewer government impediments to private money issue, and (2) advances in information technology where private liabilities are electronically transferred.

In another theoretical paper, Williamson (2004) explored the implications of private money issuance for the effects of monetary policy, for optimal policy, and for the role of fiat money. He uses a locational model and finds that when private money issue is permitted, it dramatically changes the nature of optimal monetary policy. He concluded that private money has the advantage of being "elastic," because its quantity can respond to unanticipated shocks in ways that the stock of fiat currency cannot. Thus, in the presence of private money, fiat currency is no longer used in transactions involving goods, and (together with central bank reserves) it only plays an important part in the clearing and settlement of private money returned for redemption. In his model, private money is redeemable in outside money instead of commodity money (either gold or silver), which was a common feature of the private money systems observed in history.

### *2.9 Payments Systems and Electronic Money*

Hernandez-Verme et al. (2004a, 2004b) were among the first to propose private electronic money that closely resembles some of the virtual currencies existing today. They introduce an Internet economy with two outer networks and one central network, where contracts are enforced. In addition to fiat money, there are two types of private electronic money issued by two different producers: one local, which is only accepted in one network, and one global, which is accepted in both networks. Each private electronic currency is issued by a specific producer and coexists with fiat money. In this model the two electronic currencies and fiat money circulate in equilibrium, and they focus on the discount rate at which the local private electronic money will be sold.

## 3 The Industry of Micropayment Services

There are many different definitions of what constitutes a micropayment, which mostly vary according to the upper limit of the price of each transaction. We believe that there is no single definition that is, a priori, better than the others, but we have to pick one in order to move forward with our study. Thus, for the purposes of this study we have chosen to define a micropayment as an online or mobile transaction with a value below $6.50. In the remainder of this section we will present what we believe to be the main characteristics of the micropayments industry.

In this chapter, we focus our attention on some particular aspects of the micropayment system, i.e., the Internet payments system for the micro-products market. We start by describing the recent evolution of this industry. Next, we describe the different niches in this market, of which we will focus on two: transaction grabbers (as in Goldsbury, 2012, February) and virtual currencies (although we are aware that there are more niches, they tend to overlap in these two). We believe it is very important to describe not only the market niche of virtual currencies, but also the second niche labeled as transaction grabbers, highlighting the fact that transaction grabbers are, among other things, facilitators of the use of virtual currencies.

## *3.1 Recent Evolution of the Micropayments Industry*

We now turn to summarizing the main elements that have characterized the recent evolution of the environment for the micropayment industry, which was a necessary precursor to the development of virtual currencies as we know them now. Most of this section is based on Burelli et al. (2011). The evolution of the micropayments industry has been enabled by three mutually reinforcing trends, which we list and analyze below.

(a) **The growth of broadband infrastructure and of e-commerce**

According to the European Central Bank (2012), by the end of 2011, the number of Internet users in the world had reached 2267 million, approximately 33 % of the global population. The number of Internet users in the world in 2000 was of 361 million.

Western European broadband penetration has grown from 19 % of households in 2004, to 56 % at the end of 2009; in addition, a further 9 % of households have access to mobile broadband. Building on this, widespread consumer adoption of online payments has fuelled considerable growth in global e-commerce. This behavioral shift, supported by a thriving online payments industry, has increased online spending from £150 billion in 2004 to over £350 billion in 2009. Burelli et al. (2011) highlight that online shopping is so popular that even during the global recession of 2008/2009, as UK high street retailing revenues contracted by approximately 2.5 %, online sales rose by 17.8 % year on year. Moreover, a survey of UK consumers showed that more than two-thirds of the population aged 14 or older bought goods and services online in 2010.

(b) **The growth of social networks, online gaming and virtual goods-related businesses**

The online gaming sector has rapidly gained popularity among Internet users. The period 2007–2009 saw a proliferation of online games with built-in virtual currency systems and virtual goods stores. Currently, these systems attract over 400 million active users every month. The use of these online games has been driven by integration into social networks. For example, FarmVille, a game designed by Zynga, is accessed by more than 63 million active users who each month spend an average of 15 min a day in the game.

Typically, virtual goods are bought for small sums of money within online games and are supported by a range of micropayment-style processes. Big firms are starting to take these markets seriously. For example, in May 2013 Amazon introduced its own virtual currency, called Amazon Coins, which can be used to buy games, applications or other in-game currencies (for more about Amazon Coins see Metz, 2013, February 5). In 2011, the overall market for only virtual goods in the US was headed towards $2.9 billion for 2012, against $2.2 billion in 2011 and $1.6 billion in 2010.

(c) **The emergence of new online payments services and user interfaces**

Value Partners estimates that the European micropayments market was worth 6 billion euros in 2011, and is set to grow to over 15 billion euros by 2015. According to Hernandez-Verme et al. (2004a), the use of electronic equivalents of fiat money became excessively costly, especially because of the size of the fees charged relative to the value of the micro-products. What seemed to be a serious problem in the micro-product market was that transaction costs were so high they precluded very small transaction values: the currency available was not sufficiently divisible, because it could not be used for transactions of a value lower than the transaction costs. The presence of these indivisibilities precluded some trade in this market (Fig. 2).

Reducing the scope of these indivisibilities by introducing a new electronic medium of exchange that is cheap and accepted in different Internet communities increases the scope and the size of e-commerce. As in Glenbrook Partners (2011), comScore Inc. indicates, 29.7 % of social gamers have neither the ability nor the

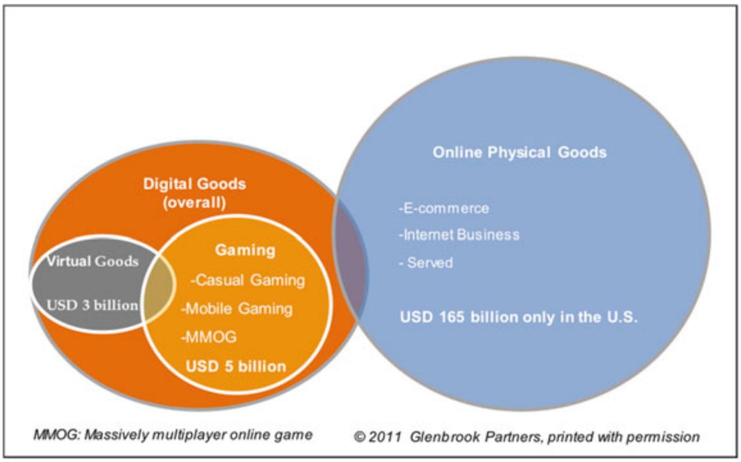


**Fig. 2** Market size of online trading in the US in 2009

**Table 2** Parameters for assessing virtual currencies and transaction grabbers

| | | |
|---|---|---|
| Payment functionality that supports many digital content providers that may be available also for either online or off-line payments across multiple retail industries | **Openness**<br>Open-Closed<br>← O–C → | Payment functionality that supports one or very few digital content provider (s) and works in a closed transaction environment |
| Transaction funded on the basis of an instant, real-time transaction | **Payment finality**<br>Real time-Both-Pre-paid<br>← RT B PP → | Transaction enabled by advanced deposit of value prior to the transaction |
| Transaction denominated by monetary currency value | **Type of currency used**<br>Real money[a]–Virtual currency<br>← RM–VC → | Transaction denominated by units other than legal tender |
| The settlement of micropayment transactions made on a one-by-one basis | **Rule for settlement**<br>Single payment-Both-Aggregator<br>← SP B A → | The settlement of multiple micropayment transactions that are processed in an aggregated manner |

Elaborated by the author. *Source*: Burelli et al. (2011)
[a]This refers to actual fiat legal tenders

means to pay for virtual currency with cash options. Companies like Google, PayPal and Amazon have leveraged their respected brand names and established trust-based customer relationships to enter the financial services market, while incumbent payment and banking infrastructures have increased their reach and new entrants are trying to establish themselves. Even so, according to Talbot (2012, March), Osama Bedier, Google's Vice President of Payments and of Google Wallet, states that only about 7 % of retail sales occur online, compared to the 93 % that is still spent in person at stores.

Consumers and merchants are driving the alternative payments market as they look for new ways to pay and get paid. Mobile commerce has lowered the costs for merchants to accept old and new types of payments. Take Square, founded by the creator of Twitter, allows people to accept credit cards with their smart phones.

The parameters taken into account when analyzing the examples mentioned below are based on Burelli et al. (2011), and they are displayed in detail in Table 2.

In the next two sections, we present a detailed description of each of the market niches of the micropayments industry.

## 3.2 *The Transaction Grabbers*

In the first niche, we find micropayment companies playing the role of intermediaries between senders and recipients of money. We will call them the transaction grabbers. Mainly, they all work like peer-to-peer payments systems, as in

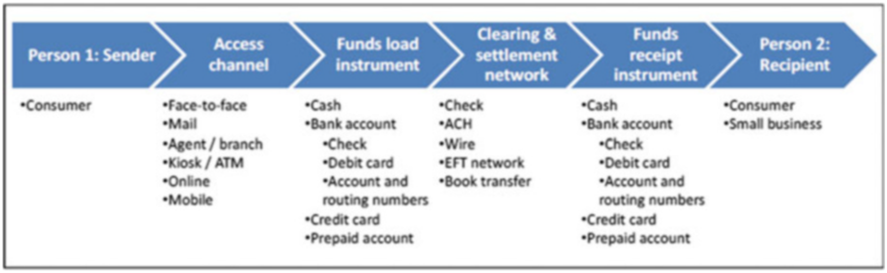


**Fig. 3** The peer-to-peer (P2P) payment lifetime cycle. © 2011, J. Windh, printed with permission

Fig. 3. Table 2 presents the cost structure of some of the existing electronic payments systems and Table 3 presents the way that these systems normally work. According to InvestingAnswers, peer-to-peer payments systems (P2P) are an online technology that allows customers to transfer funds from their bank accounts and credit cards to another individual's account via the Internet or a mobile phone. We think these should also include pre-paid accounts or other sources of funds.

For example, PayPal introduced their micropayment product worldwide in 2008. PayPal is a Web-based application for the secure transfer of funds between members' accounts. There is no application fee for the user, and no cost for sending money through the service, but there is a fee structure for those members who wish to receive money. That fee was still high for products with prices around ¢5–¢10, which is why they released a special micropayment service. In July 2011 PayPal bought Zong for $240 million. One of the main reasons for this was to attract this market on a full scale. According to Thompson (2011, July), Zong allows one to pay for purchases from one's mobile phone or computer by adding the payment to your wireless bill. Zong verifies one's wireless phone number and account, and clears the payment on your mobile phone bill: there is no credit card number, expiration date, or billing address to enter. They charge a transaction fee of 5–10 % depending on the volume of the sale, without setup or monthly fees.

Visa launched its own micropayment system in Australia in 2010. It was called Payclick, and it is similar to PayPal's micropayments product: the system just asks one to fill in one's password and the transaction is done; they do not reveal their fees until one applies for an account (which means giving information about one's business), but they claim to be very competitive. Visa has recently declared their interest in opening Payclick in the US and Europe as well.

Almost all the transaction grabbers share the common characteristic that they do not require the clients to reveal their financial information when the transaction is made, since doing so would involve more risk and it would also be annoying if the client had to do this on every low value purchase.

**Table 3** Main characteristics of transaction grabbers

| Transaction grabber | Application or setup fee | Monthly fee | Transaction fee charged to the recipient | Openness | Payment finality | Type of currency used | Rule of settlement |
|---|---|---|---|---|---|---|---|
| Zong | None | None | 5–10 % transaction fee | O | RT | RM | SP |
| Payclick (only for Australia and some cities in the US) | Not revealed until applying | Not revealed until applying | Not revealed until applying | O | B | RM | SP |
| PayPal | None | None | ¢5 plus 5 % for transactions under $12 | O | B | RM | B |
| PayNearMe | Around $199[a] | Around $1199 (annual)[a] | • $2.99, cash payments up to $300[a]<br>• $3.99, payments from $300 to $500[a]<br>• $4.99 for payments up to $1000[a] | O | RT | RM | SP |
| Dwolla | None | None | • None for transactions up to $10<br>• ¢0.25, all transactions above $10 | O | RT | RM | SP |
| Google Checkout | None | None | Based on monthly sales:<br>• Less than $3000: 2.9 % + $0.30 per transaction<br>• Between $3000 and 9999.99: 2.5 % + $0.30<br>• Between $10,000 and $99,999.99: 2.2 % + $0.30<br>• Above $100,000: 1.9 % + $0.30 | O | RT | RM | SP |

*Source*: Official websites

[a]This information does not appear in the official PayNearMe website

## 3.3 Virtual Currencies

The second niche is occupied by virtual currencies. Its main use is to buy virtual goods in online games, social networks and MMORPG. On the one hand, Facebook Credits are an example of a virtual currency in online games and social networks (their value was 1 credit for US$0.10). On the other hand, Linden Dollars in Second Life are an example of virtual currency that works in a virtual world.

The growing mass of online gaming and social networks has facilitated the rapid increase in the global virtual goods market. According to Burelli et al. (2011), players of online games and members of virtual communities are spending more and more on virtual goods to enhance their gaming experience. In 2010, Europeans spent over $1 billion on virtual goods, the Asian market is already worth over $5 billion annually, and Americans will spend over $2 billion by 2011. Their growth will continue as it is becoming easier and cheaper to be a part of this market.

Some virtual currencies are exchangeable with other virtual currencies and a few with fiat money. One can purchase them by the payments' services explained above and/or trade them at web sites like Virwox or First Meta Exchange. Because there are ways to create wealth in these virtual worlds and online games, this opens an interesting area of business to study. For example, players of Entropia Universe (an MMORPG) already exchange real money for virtual currency. Further, virtual money they make in the game, through virtual hunting, mining, trading or other activities, can be cashed out into real money (the virtual currency Project Entropia Dollars has a fixed 10:1 exchange rate to the US dollar on the official site; nevertheless, its value fluctuates if one exchanges it at other currency exchange sites). Governments in different countries are aware of this, but not much has been done. Many of them consider taxes when virtual currencies are converted to real money, but it is very difficult to supervise this due to the ease of doing these activities "under the table." According to Sandqvist and Zackariasson (2010), the USA National Taxpayer Advocate 2008 Annual Report to the Congress recommends that the IRS start working on how to tax economic activities within these arenas. According to Salomon and Soudoplatoff (2010), in 2007 the Chinese government made the first important attempt to regulate a virtual currency (named QQ coins). These tokens were first used as play-money for virtual gifts, but businesses started accepting them in exchange for real goods because users of this coin were frustrated by the nation's banking infrastructure. The Department of Commerce barred the practice due to the central bank's concerns of a possible impact on the value of the Renminbi. The only permissible trade was limited for virtual goods and virtual services.

Credit card companies are aware of the potential of these new markets; for example, American Express in 2011 bought a company called Sometrics, which in 2010 turned over 3.3 trillion units of virtual currency on their platform. One can buy virtual goods such as gold coins or whatever it may be. According to Leber (2012, March), this acquisition allowed the company to tap into the massively growing space of online gaming and to develop capabilities to manage virtual currencies, a business that is projected to nearly double by 2014.

According to Yamaguchi (2004), two factors about virtual worlds need to be taken into account. First, they have no measure to control money supply. The balance between goods and money is determined by collective consumption/saving decisions by players. Secondly, there are no interest rates in virtual worlds in general. The absence of interest rates, ceteris paribus, reduces incentive for saving and raises that for consumption. Since many virtual worlds do not have inflation of the general price level, we cannot say in general that consumption is preferred in virtual worlds relative to the real world. Nevertheless, there should still be greater incentive for consumption compared to the case in which there are interest rates.

There are other types of virtual currencies that work directly in the global economy. One example of such is Bitcoin, defined by its creator Nakamoto (2008) as a purely peer-to-peer version of electronic cash that allows online payments to be sent directly from one party to another without going through a financial institution. The main challenge for developing this kind of currency is the "double-spending" problem. According to Lowenthal (2011, June) and Cohen (2011, July), Bitcoin's solution was to ensure that each coin was its own certificate of authenticity. As soon as a transaction occurs, the recipient publishes the transaction to the global Bitcoin network. Now every Bitcoin user has evidence that the coin has been spent, and users will only accept that coin from the new owner. Also, according to the European Central Bank (2012), Bitcoins are almost 100 % anonymous and are divisible to eight decimal places, enabling their use in any kind of transaction, regardless of the value. According to Cohen (2011, July, p. 1): "In the Bitcoin system, a new coin is produced whenever a computer can calculate an answer to a difficult problem, and then attaches that answer to a digital record of every transaction of every Bitcoin ever traded." Anyone is free to create a new coin, within certain limits, by providing computer power that helps to prove that it is in fact a valid Bitcoin. Bitcoins can also be traded for dollars and they are accepted in different online retail stores an also in a few "bricks-and-mortar" retail stores and cafés. (For the list of the different currency exchange business, and stores that accept Bitcoins, visit Bitcoin Wiki web site). Also, its target market is not only digital and virtual goods; one can also obtain physical goods in some retail businesses. In 2011 there were seven million of these "coins" in circulation, and the rate of increase (currently, 50 coins are added every 10 min) will slow each year until the number tops out at 21 million coins around 2025. However, as the European Central Bank (2012, p. 25) states in their report, "Bitcoin is still quite immature and illiquid (the 6.5 million Bitcoins are shared by 10,000 users) which is a clear disincentive for its use."

Another example is Ven currency. The value of Ven floats against other currencies and the price is based on a basket of currencies, commodities (like gold, silver, Brent crude) and carbon futures, which is intended to make the value of this currency very stable because no single unit has a strong influence relative to the other influences in the basket. Also, the introduction of carbon to the basket is intended to support and stimulate demand for carbon credits and social impact development, driving offsets for every transaction used with Ven. At the moment, $1 is equivalent to 9.35 Ven. Ven trades against other major currencies and is mainly used in an online community called Hub Culture, a site when members can trade goods and services as well as knowledge. Nevertheless, one can also use it in Pavilions (retail places specially developed to accept the currency). According to Stalnaker (2012a, January 11), at the beginning of 2012 over $100 million in assets were available for purchase in 130 hubs worldwide using Ven. As opposed to Bitcoin, Ven does not provide anonymity, and is generated centrally (though exchanged).

Nevertheless, almost all of today's existing electronic currencies (with the exception of Bitcoin and Ven) are surrogates of fiat money: they are denominated in fiat currency, and their purchasing power fluctuates with the purchasing power of the denominating currency. Moreover, except for Bitcoin, they are fiat in the sense that there is no backing of these electronic monies, and they are thus not redeemable to the issuers. For example, Avios is a currency that one accumulates for traveling on Iberia airplanes and that one can trade for traveling tickets and some products in partners' stores; one may also transfer Avios to other Iberia clients as gifts or one could buy them, but they are not redeemable in fiat money. The exchange rate between Avios and euros depends on many things. First, the exchange rate differs depending on whether one is purchasing or transferring Avios; second, there are economies of scale, since the euros one pays increase less than proportionately to the amount of Avios traded (for example 2000 Avios are worth 54 euros and 8000 Avios represent 164 euros).

On the one hand, since Avios only works for three airline groups (Iberia, Vueling, British airways) and a limited retail market, it is unlikely to become a generally accepted transaction medium: people who are not interested in their offers may not value them at all, and might not want to accept Avios currency.

On the other side of the spectrum, we have the case of Amazon Coins. Because Amazon is a very popular company, it is easy to imagine that such a currency would be more generally accepted than others. Until now, Amazon Coins have worked only in the Amazon Appstore to buy virtual goods and currencies in online games, apps and some digital products such as movies or music. Nevertheless, Amazon is a company that has also a big and diverse market of real products (books, computers, clothes, etc.). If their currency works for digital and virtual goods, it will not be difficult to imagine that Amazon could take this currency as an official or alternative medium of exchange at their site (or other sites), but only time will tell.

Amazon should learn from the mistakes made by Facebook, when in mid-2010 they introduced their promising virtual currency called Facebook Credits. Game developers had many problems in terms of pricing their own in-game currencies, and the charges that Facebook took per sale. Also, users complained that the currency complicated their purchase experience, and that it was easier to do it with the standard payment systems. The Facebook Credits initiative was officially shut down in February 2013. For some experts, it was expected that 1 day Facebook Credits could expand their reach on virtual, digital and real goods markets, but this is clearly no walk in the park. Although Amazon may face problems of the same nature, it has two advantages: first, as in Hudson (2013, February 9), they are not asking developers to make any modifications to their apps and they are charging the same amount per sale as they did before. Secondly, they already possess a large market of real goods, unlike Facebook that still focuses on virtual worlds and virtual goods. This way Amazon Coins may have an easier task if the time comes and the company decides to expand the currency to real goods markets.

**Table 4** Main characteristics of virtual currencies

| Virtual currency | Openness | Payment finality | Type of currency used | Rule of settlement | Exchange rate in USD (selling price) |
|---|---|---|---|---|---|
| Bitcoin (BTC) | O | RT | VC | SP | $377.51 for 1 BTC (03-Oct-2014) |
| Ven | C | RT | VC | SP | $1 for 10.2 Ven (03-Oct-2014) |
| Avios | C | RT | VC | SP | Depends on how much Avios one buys. For example, 2000 Avios are 54 euros and 8000 Avios are 164 euros (03-Oct-2014) |
| Project Entropia Dollars (PED) | C | RT | RM | SP | $1 for 10 PED (03-Oct-2014) |
| Linden Dollars (L$) | C | RT | RM | SP | $1 for L$236 (03-Oct-2014) |
| Facebook credits (out of the market) | C | B | RM | SP | 1 credit for US$0.10 (01-Dec-2013) |
| Amazon coins (AC) | C | B | RM | SP | 100 AC for US$1 (03-Oct-2014) |

Elaborated by the author. *Source*: Official websites

There are several advantages to these kind of virtual currencies: their value would not fluctuate with the value of fiat currencies, but would instead depend on the value of the commodity bundle backing it and/or maintaining its reputation as an issuer. According to Hernandez-Verme et al. (2004a), this type of electronic currency has similarities with commodity money; it is now the product bundle that serves as the anchor. This new form of electronic money has the potential to become a currency with more stable value than fiat currency. In addition, a global Internet currency would eliminate the need for foreign exchange. This is also why the issuer of such a currency should be a firm that is recognized worldwide, like Amazon or Facebook (that has a user base of some 800 million people worldwide).

Hernandez-Verme et al. (2004a, 2004b) claimed that three technical elements are necessary for any virtual currency to be accepted by the public: low cost, security, and privacy. In particular, these authors highlight the great importance of low costs in micropayment transactions, practically regardless of the payment method utilized. They also point out, nonetheless, that there are alternative ways of reducing costs. In this regard, they emphasize the importance of the avoidance of expensive intermediaries, such as banks and credit card associations in this kind of transaction, since they could act as an indivisible sunk cost that may reduce the firms' margins and their profitability within the network. According to Mas (2012, March, p. 3), "about 2.5 billion people in the world do not have access to a bank account," and because of this, some of them have no access to these kinds of markets. Security plays an important role in generating trust in an electronic environment: security becomes a must for electronic payments, where cryptographic security mechanisms, including encryption and digital signature schemes, are often used to provide the desired security for the transactions. Finally, Hernandez-Verme et al. (2004a, 2004b) argued that privacy—the third element on the list—has become a much bigger concern in today's information world, so much so that an ideal virtual currency should provide anonymity, or at least a high level of privacy, so that it can compete against fiat money.

Bitcoin satisfies two of the three characteristics mentioned above: it has a low cost and it is anonymous, but it has a bad reputation for its safety and has been the victim of speculation, which has caused its exchange rate to fluctuate unpredictably over time. In Table 5 we provide an historical review of the significant fluctuations in the exchange rate of Bitcoin. One reason for this could be that, as Simonite (2012, March, p. 14) argues: "In the United States and Europe, Bitcoin's meteoric rise was mostly driven by speculators; hardly anyone used the currency to actually pay for goods and services." Also, according to Fuller (2014, March 3), in February 2014 MtGox, the

**Table 5** Historical exchange rate of Bitcoin as traded by Mt Gox (Mt) and Plus500 (P500) (USD per unit of Bitcoin at the close of trade)

| Date | Exchange rate | Important event |
|---|---|---|
| 04/25/2010 | ¢0.3 (Mt) | Bitcoin trade publicly for the first time (1000 go for 0.3 cents each) |
| 02/10/2011 | ¢0.98031 (Mt) | Bitcoin receives a write-up on Slash-dot for achieving dollar parity |
| 04/20/2011 | $1.1421 (Mt) | Forbes publishes "Crypto Currency," a profile of Bitcoin |
| 06/01/2011 | $9.57 (Mt) | Gawker runs a story about Silk Road, an online bazaar of illicit goods that accepts Bitcoins |
| 06/09/2011 | $28.919 (Mt) | Bitcoin reaches its peak value |
| 06/19/2011 | $17.51 (Mt) | Mt. Gox, the largest Bitcoin exchange, admits its database was compromised and user information leaked |
| 07/29/2011 | $13.49832 (Mt) | Wallet service MyBitcoin.com becomes inaccessible; 6 days later, it comes back online with 51 % (roughly $250,000) of its Bitcoin holdings missing |
| 11/18/2011 | $2.04999 (Mt) | Bitcoin exchange rate falls dramatically |
| 01/04/2012 | $4.8808 (Mt) | Bitcoin exchange rate starts to grow again |
| 08/12/2012 | $11.67001 (Mt) | Exchange rate continues to grow |
| 23/09/2013 | $133.22 (Mt) | Bitcoin gets more media attention after exponential growth |
| 05/01/2014 | $890.38 (P500) | Bitcoin exchange rate rose dramatically |
| 23/02/2014 | $556.5 (P500) | Bitcoin exchange rate falls after Mt Gox filed for bankruptcy |
| 02/10/2014 | $371.20 (P500) | Latest exchange rate |

Elaborated by the author. *Sources*: Bitcoin Charts and B. Wallace (2011) biggest Bitcoin exchange site at the time, shut down claiming for bankruptcy, consequence of missing 850,000 Bitcoins, due to a flaw in their systems. Nevertheless, is not all bad news for Bitcoin: according to Carroll (2014, July 2014) Tim Draper bought 29,566 Bitcoins (undisclosed price) that were auctioned by the FBI after they seized them from Ross Ulbricht the alleged founder of Silk Road after facing drug, computer hacking and money laundering conspiracy charges. Also, according to Bishop (2012, December 7), Bitcoin-Central, a known exchange institution for Bitcoins, was approved to operate as a bank under French Law. Although Bitcoin-Central will not issue debt for the moment, with formal financial institutions accepting deposits in this new currency and public figures investing on them, people and corporations may start to take Bitcoins more seriously.

## *3.4 Benefits and Disadvantages of Virtual Currencies*

In this section, we present a summary of what are believed to be some of the pros that an "ideal" virtual currency should have to be widely accepted, together with the cons that any virtual currency may find along its way. We based our lists on the experiences that the existing virtual currencies have been through and on their actual characteristics. It is crucial to take each of the elements in this list into account for a proper analysis of existing virtual currencies; but it is equally important to consider them when designing the main characteristics of prospective virtual currencies (this part is mostly based on Azmaan, Giancarlo, and Tunmise (2011a, 2011b), Glenbrook Partners (2011), Simonite (2012, March) and Walsh (2009, August)).

Before going on to the next subsection it is important to clarify that these currencies achieve the three basic functions of any object used as money: (1) medium of exchange, because they work for exchanging different types of goods and services and facilitate this exchange by avoiding the double coincidence of wants; (2) unit of account, because the price of the majority of the goods and services that one purchases with them are denominated in the specific virtual currency that will be used to purchase them; and (3) store of value, because these currencies can be saved or stored and be retrieved in the future. If we add the function of *Standard of deferred payment* it is clear they do not achieve it, because they are not (yet) recognized or officially used to make future contracts.

### 3.4.1 Advantages and Benefits of Virtual Currencies

Below, we list what we believe are the advantages and benefits that an ideal virtual currency should possess. This is not by any means intended to be an exhaustive list. An ideal virtual currency should:

1. Allow almost anybody to buy goods online without the need to use a credit card or disclose private information.
2. Act as a substitute currency that allows customers to buy, sell, and trade items without having to use real-world money.

3. Provide users with anonymity or privacy up to a point.
4. Allow users and issuers to generate revenues and create profits online, which can then be exchanged for other goods (real and/or virtual).
5. Reduce cost of entry to the market for producers, consumers and intermediaries.
6. Be more practical and easier to use than conventional payment systems, for both costumers and sellers.
7. Have a decentralized issuance (like Bitcoin) or centralized, but only from an issuer that cannot induce inflation (like Ven).
8. Allow deposits and transactions to be made, either through a middleman or without.
9. Provide faster transfers than conventional financial institutions.
10. Ubiquity: it must be present and available almost everywhere and anywhere.
11. Be accepted depending on the good reputation of the issuer, as with legal tenders.
12. Be recorded in a public ledger, the equivalent of check clearing between bank accounts.
13. Help solve the double-spending problem.
14. Have encrypted transactions, making them friendly-fraud immune.
15. Be safer and a better store of value than fiat money. It may work as a deflation/inflation hedge, in the sense that it provides protection against a currency losing its purchasing power. It typically involves holding an asset that is expected to maintain or increase its real value over a specified period of time and, thus, can be used for transferring purchasing value to the future.
16. Be sufficiently expandable and divisible to make micro/macro transactions.

### 3.4.2 The Drawbacks of Virtual Currencies

Next we list the drawbacks that a virtual currency may face along the way:

1. It may be vulnerable to system failures.
2. If there is no sufficient regulation, it could be used to pay for "illegal" activities or products such as money laundering or buying prohibited products or services. Like in the case of Silk Road, for more on this see Hill (2014, January 16).
3. Its valuation can fluctuate in some cases.
4. As long as it is not officially recognized and accepted by formal financial institutions it may pose a difficulty for making future contracts or floating against fiat currencies.
5. It may be vulnerable to the risk of unknown technical flaws.
6. It will be hard to be accepted for paying taxes or as bank reserves.
7. Decentralization is both a curse and a blessing if there is no valuation guarantee.

Notice that most of the disadvantages listed above are not particular to virtual currencies: historically, fiat currencies have also been used for money laundering and the financing of illegal activities—such as illegal drug dealings or gambling.

However, because of their lack of intrinsic value, fiat currencies are also prone speculation, and particularly to the kind of self-fulfilling attacks that make their value fluctuate without any noticeable alteration in the fundamentals of the economy. Finally, we should also keep in mind that both inflation and/or hyperinflation crises might severely hinder the acceptability of a currency and the credibility of the government in general, and of monetary authorities in particular (for more on the subject see Wolman, 2012).

## 4 The Future of Monetary Policy

The change of the conventional means of payment from paper-based systems to electronic-based systems, together with the use of alternative means of payment, has been growingly at tremendous speed over the years, changing the incentives and costs structure underlying particular institutional arrangements in payment systems. Thus, the ratio of central bank money to total value of payments has decreased considerably. This development gives rise to concerns about the future role of money and the central bank. Although we are still far from living in a cashless society, the role of monetary policy is on the verge of changing dramatically, especially because of two elements: a) the falling use of cash as a form of payment, and b) the changes of regulation.

### *4.1 The Falling Use of Cash as a Form of Payment*

The use of cash as a payment method has clearly been decreasing over the years, substituted by cards, mobile devices and alternative means of payment such as described in this chapter. According to See-To et al. (2007, p. 63):

> The costs of handling cash are high compared to that of electronic money. Printing, distributing and controlling cash are estimated to cost approximately for a developed economy 0.75% of annual GDP and an emerging economy 1% to 2%. Social savings of using electronic micropayment means over cash are substantial.

The role to be played by the central bank in the near future will be as important as it is today, and will remain the same for quite a while. As Schmitz (2008) shows, almost all of new payment instruments in the retail payment market (e.g., electronic bill presentment and payment; person-to-person payments via PayPal; stored value pre-paid cards; phone-based payments) are linked to the banking system and eventually settle in central bank money. The demand for virtual currencies that are not denominated in fiat currencies is still low, but is increasing at such a pace that it is important to improve the way we study them. The existence of private monies is hardly new, but technological innovations could lead the way to a world where private monies play an important role in the world's economy (Fig. 4).

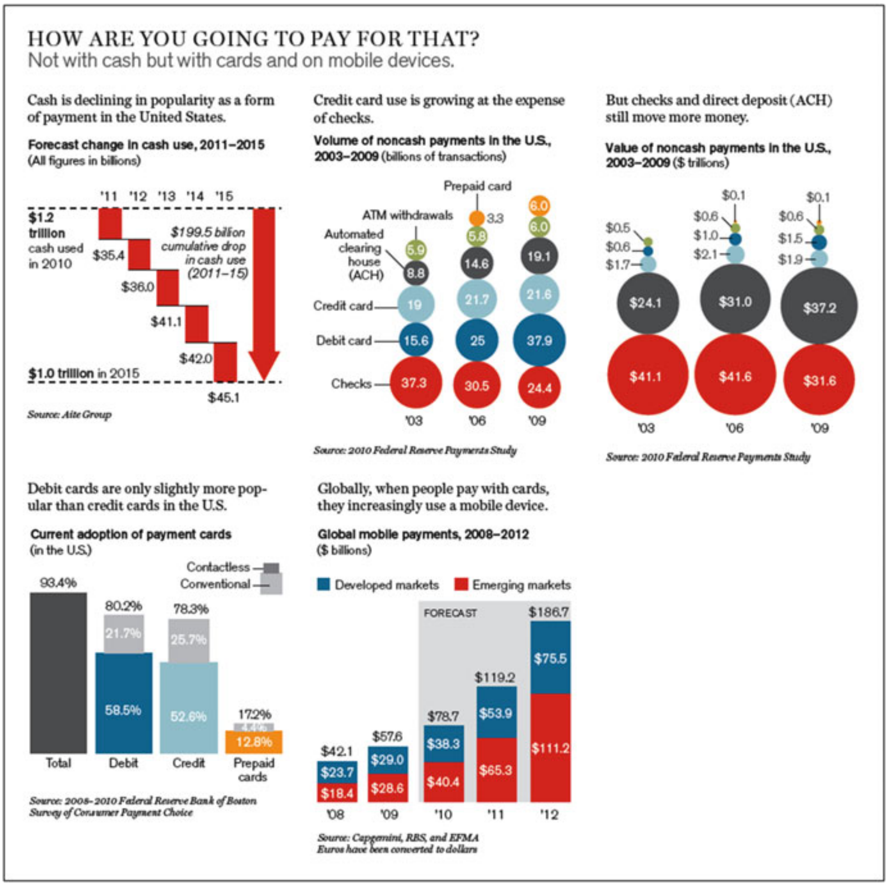


**Fig. 4** The declining use of cash in the US. © 2011 J. Pontin, used with permission

## *4.2 Regulation*

Money and banking are highly regulated improvements on technology in the payment systems, so they have a slow effect in the change of their policies. According to Mas (2012, March, p. 3) "the intricacies of regulation make it difficult for banks to be truly customer-centric."

According to Schmitz (2008), in recent history central banks have demonstrated their determination and their political ability to maintain control of the monetary system in the face of institutional change in the payments system and to actively shape themselves to adapt to any changes. They have a large range of instruments at their discretion to react to but also to influence institutional change in the economy-wide payment system, and they can adapt the instruments of monetary policy implementation and their own payment systems policies to cope with institutional change in the payments system. Changes in the reserve-maintenance system of the generally accepted medium of exchange (GAME) are of particular relevance in this respect (i.e., the averaging of minimum reserve requirements, the averaging period, its relation to the interval of central banks' refinancing operations and the potential employment of minimum reserves for settlement purposes). Nevertheless, the effects of QQ coins in China and the fact that Bitcoin-Central has obtained a license to work as a bank, are sufficient reasons to ask whether central banks' tools are really that strong.

Actually, one can only pay one's taxes with fiat money, and virtual currencies do not allow one to create a positive return by saving or lending (other than to one's friends, such as at RipplePay) or making futures contracts on a large scale, and, thus, fiat money will remain prevalent. Nevertheless, it is important to improve the way we study these markets to develop the appropriate banking policies. One example of how far we still are from adapting to this alternative means of payment is the fact that almost all virtual currencies are not taxable. The profits one makes online can be converted into real monies without tax deductions. Also, as in the European Central Bank (2012), most virtual currencies are not confined to a particular country or currency area, which complicates law making, regulating and law enforcing.

## 5 Conclusions

The analysis carried out in this chapter attempts to provide readers with insight into the list of tasks that lie before academic researchers in furthering their study of both virtual currencies and the micropayment systems. It intends to reach a more unified way of using the definitions of virtual currencies, micropayments and virtual and digital goods.

Modern transaction grabbers have facilitated the emergence of virtual currencies by lowering the costs of entry to this new market and by making this alternative means of payment easier to manage. Virtual currencies are still in an early stage of development; as of now, they mostly work in the micropayments market for virtual goods. Thus, at present they do not represent a real threat to price and financial stability, nor a widely recognized substitute for fiat money, as the European Central Bank (2012) states. But the impressive recent growth of this market's size and scope—as in the case of Bitcoin and Ven or QQ coins in China—demonstrates that sooner or later they will come to play a crucial role in the design and implementation of monetary policy and on the future discussions of the political and economic agenda.

The potential benefits that these monies may provide are something we cannot ignore, since although they are not perfect, many of their defects are also similar to the ones associated with fiat money. It is not only a matter of how to control or regulate these innovations. We also have to learn from their technologies and the reasons why they were created. Ultimately, money has been a changing technology throughout history, and maybe these currencies are not only introducing new kinds of monies, but are setting the basis for the next technological step that even fiat money will take. A smaller role of the central bank need not be something to be afraid of, as in Bishop and Green (2012, p. 1402) indicate:

> As governments take risks with the value of money through massive experiments such as quantitative easing, the system of national monetary monopolies of fiat currencies may increasingly be challenged by capital markets that respect no national borders. We now live in a globalized world, where citizens are better able to avoid and protect themselves from such governmental control.

It is plausible that the generalization of alternative ways of payment could also prevent central banks from acting in an irresponsible way, for political purposes.

We must point out that there is a significant dearth of academic studies on these emergent currencies. However, the work of Schmitz (2008) presents an interesting proposal for studying the effects of private currencies on monetary policy, from an institutional perspective. Also, the works by Castronova (2001, 2003, 2007, 2008a, 2008b) provide a helpful way to study the way that virtual currencies are used inside virtual worlds and online gaming.

It seems crucial for both academics and banks to reconcile the benefits of a world where fiat and virtual currencies coexist, and to try to find ways to integrate physical cash into the electronic world. Academics could start changing some aspects in the modeling of monetary policy, while the banks could start being more flexible in a way that allows their clients to take full advantage of this novel means of payment.

For future works we may apply a theoretical approach for studying modern systems of private electronic currencies by designing a dynamic stochastic general equilibrium that satisfies some of the arguments that we provide in this chapter. In particular, we would propose the general foundations for a theoretical framework that can be used for the analysis of virtual currencies. We would like to analyze an economy where fiat money and a virtual currency (that is produced by a private entity) coexist in spite of having different real rates of return. We think that, at least in a primary stage, this will be possible because each of these currencies is used for purchasing different kinds of goods and they perform a different function in the economy: then, the real rate of return will not be the only thing that agents look at when deciding how much to hold of each currency. We would develop a model that is influenced by the complementary lines of research that were discussed in Chap. 2. Some features that we may add to the model are: debt issuance, default, anonymity and privacy.

Along with the model, we may also update the challenges to both law makers and policy makers on how to design new settlement rules, how to regulate and supervise the financial system, the elements needed for this regulation and supervision to be successful and the new technological advances that legal tender or other virtual currencies may make in the future. Finally, we may compare and complement the economic concept of money with the perspectives and concepts of other sciences such as anthropology and sociology. For instance, we may use Niklas Luhmann's concept of money as a social contract (Luhmann, 2000) and the need for trust for this medium of exchange to work.

**Acknowledgments** We would like to gratefully acknowledge the support of Stan Stalnaker, founding director of Hub Culture, for providing us helpful information about virtual currencies.

## Appendix

We included the following papers based on various criteria:

- Papers 11 and 12, because they were the only papers that model a private electronic currency similar to the ones that exist nowadays; they also helped us to design the structure of this work.
- Paper 15, because it is the paper that the creator of Bitcoin uploaded to the web when Bitcoin started and explains how the Bitcoin system works.
- Paper 20, because we consider that it provides reliable information about the state-of-the-art of virtual currencies and their regulations.

**Table 6** Selected academic papers

| Academic papers | | |
|---|---|---|
| | Author(s) | Peer-reviewed |
| 1 | Capie, F.H., Tsomocos, D.P. and Wood, G.E. (2003) | Yes |
| 2 | Castronova, E. (2001) | Yes |
| 3 | Castronova, E. (2003, February) | Yes |
| 4 | Castronova, E. (2008a, 2008b) | Yes |
| 5 | Castronova, E. (2010, February) | Yes |
| 6 | Costa, C. and De Grauwe, P. (2001) | Yes |
| 7 | Erb, C. B. and Harvey, C. R. (2013) | Yes |
| 8 | Freedman, C. (2008) | Yes |
| 9 | Freeman, S. (1996a) | Yes |
| 10 | Freeman, S. (1996b) | Yes |
| 11 | Hernandez-Verme, P. L., Huang, H. and Whinston, A. B. (2004a) | No |
| 12 | Hernandez-Verme, P. L., Huang, H. and Whinston, A. B. (2004b) | No |
| 13 | Irwin, D., Chase, J., Grit, L. and Yumerefendi, A. (2005) | Yes |
| 14 | Luhmann, N. (2000) | Yes |
| 15 | Nakamoto, S. (2008) | No |
| 16 | Rochet, J. C., Tirole, J. (2006) | Yes |
| 17 | Rolnick, A. J. and Weber, W. E. (1988) | Yes |
| 18 | Rolnick, A. J., Smith, B. D. and Weber, W. E. (1998) | Yes |
| 19 | Salomon, M. and Soudoplatoff, S. (2010) | Yes |
| 20 | Sandqvist, U. and Zackariasson, P. (2010) | No |
| 21 | Schmitz, S. W. (2008) | Yes |
| 22 | Schreft, S. L. (2000) | Yes |
| 23 | See-To, E. W. K., Jaisingh, J., Tam, K. Y. (2007) | Yes |
| 24 | Smith, B. D. and Weber, W. E. (1998) | Yes |
| 25 | Temzelides, T. and Williamson, S. D. (2001) | Yes |
| 26 | Valdes-Benavides, R. A. and Hernandez-Verme, P. L. (2014) | Yes |
| 27 | Williamson, S. D. (1999) | Yes |
| 28 | Williamson, S. D. (2004) | Yes |
| 29 | Windh, J. (2011) | Yes |
| 30 | Yamaguchi, H. (2004) | Yes |

Elaborated by the author

**Table 7** Selected presentations

| Presentations | | | |
|---|---|---|---|
| | Author(s) | Institution | Established |
| 1 | Glenbrook Partners (2011) | Glenbrook Partners | Yes |
| 2 | Hansen, J. D., Soderquist, K. and Edwards, S. (2010, April 8) | Perkins Coie Lawyers | Yes |

Elaborated by the author

**Table 8** Selected books

| Books | | | |
|---|---|---|---|
| | Author(s) | Publisher | Established |
| 1 | Bishop, M. and Green, M. | The Economist Newspaper | Yes |
| 2 | Champ, B., Freeman, S. and Haslag, J. | Cambridge University Press | Yes |
| 3 | Farmer, R. E. A. | The MIT Press | Yes |
| 4 | Hayek, F. | The Institute of Economic Affairs | Yes |
| 5 | Wolman, D. | Da Capo press | Yes |

Elaborated by the author

**Table 9** Selected reports

| Reports | | | |
|---|---|---|---|
| | Author(s) | Institution | Established |
| 1 | Burelli, F. et al. (2011) | Value Partners | Yes |
| 2 | European Central Bank (2012, October) | European Central Bank | Yes |

Elaborated by the author

We included the following news based on various criteria:

- Reference 2, because it provides a detailed description of how the license of Bitcoin-Central works and what it will be able to do.
- Reference 8; we took the term "transaction grabbers" from this article because it is a functional way to describe all kinds of payment intermediaries.
- Reference 12, because it presents a complete list of reasons why Amazon Coins may work and also because this reason fits with the analysis of this chapter.
- Reference 13 announces and analyses the launch of Visa's modern P2P project. We also checked this on Visa's web site.
- Reference 14, because it is one of the most complete articles that we found about the failure of FB credits.
- Reference 16 explains Bitcoin in a simpler way than other articles.
- Reference 20 contains a practical explanation of how Ven currency works.

**Table 10** Selected newspapers and magazines

| Newspapers and magazines | | | |
|---|---|---|---|
| | Author(s) | Institution | Established |
| 1 | BBC (2012, June 20) | BBC | Yes |
| 2 | Bishop, R. (2012, December 7) | Geekosistem | No |
| 3 | Boswell, R. (2012, April) | Technology News at Canada.com | Yes |
| 4 | Carroll, R. (2014, Friday 4) | The Guardian | Yes |
| 5 | Cohen, N. (2011, July) | The New York Times | Yes |
| 6 | Fuller, C. (2014, March 03) | International Business Times | Yes |
| 7 | Glaser, M. (2010, March) | Mediashift (PBS) | Yes |
| 8 | Goldsbury, C. R. (2012, February) | Pragilematic | No |
| 9 | Green, J. (2012, January) | American Banker | Yes |
| 10 | Helft, M. (2010, September) | The New York Times | Yes |
| 11 | Hill, K. (2014, January 16) | Forbes | Yes |
| 12 | Hudson, C. E. (2013, February 9) | TechCrunch | No |
| 13 | Infosecurity (2011, March) | Infosecurity News | No |
| 14 | Kee, E. (2012, June 19) | Ubergizmo | No |
| 15 | Leber, J. (2012, March) | Technology Review | Yes |
| 16 | Lowenthal, T. (2011, June 8) | Ars Technica | No |
| 17 | Mas, I. (2012, March) | Technology Review | Yes |
| 18 | Matthews, C. (2012, July 16) | Time: Business & Money | Yes |
| 19 | Metz, R. (2013, February 5) | Technology Review | Yes |
| 20 | Miemis, V. (2011, June) | Emergent by design | No |
| 21 | Pontin, J. (2011) | Technology Review | Yes |
| 22 | Schenker, J. L. (2012, January 23) | Informilo | Yes |
| 23 | Simonite, T. (2012, March) | Technology Review | Yes |
| 24 | Smith, C. (2012, June 20) | TechRadar | Yes |
| 25 | Stalnaker, S. (2012a, January) | Cayman Financial Review | Yes |
| 26 | Svensson, P. (2009, March) | The Sydney Morning Herald | Yes |
| 27 | Takahashi, D. (2010, July 21) | VentureBeat | Yes |
| 28 | Talbot, D. (2012, March) | Technology Review | Yes |
| 29 | Wallace, B. (2011, November) | Wired Magazine | Yes |

Elaborated by the author
*PBS* Public Broadcasting Service

We chose the following blogs based on various criteria:

- Reference 9 contains a detailed explanation of how Ven currency works and also has external links that helped us with our research.
- Reference 11 has a list of the benefits of virtual currencies that relates to the arguments of our work and the blogger has a background of working for different established IT companies.

**Table 11** Selected blogs

| Blogs | | | |
|---|---|---|---|
| | Author(s) | Published at | Blogger from established institution |
| 1 | Azmaan, O. et al. (2011a) | Stanford Computer Science Faculty and Staff | Yes |
| 2 | Azmaan, O. et al. (2011b) | Stanford Computer Science Faculty and Staff | Yes |
| 3 | Castronova, E. (2007, October) | Terra Nova-Blogs | Yes |
| 4 | Castronova, E. (2008a, 2008b, July) | Terra Nova-Blogs | Yes |
| 5 | Eldon, E. (2011, December) | Technology Bits Blog, New York Times | Yes |
| 6 | Fuloria, P. (2012, June 19) | Facebook developers | Yes |
| 7 | Helft, M. (2011, April) | Technology Bits Blog, New York Times | Yes |
| 8 | Jordan, A. (2009, September) | Wall Street Journal Blogs | Yes |
| 9 | Meacham, G. (2011, June) | D-Build | No |
| 10 | Thompson, S. (2011, July) | The PayPal Blog | Yes |
| 11 | Walsh, I. (2009, August) | Ivan Walsh | No |

Elaborated by the author

**Table 12** Others

| Others | | |
|---|---|---|
| | Author(s) | Type |
| 1 | Stalnaker, S. (2012b, August) | E-mail correspondence with the authors |
| 2 | Wikipedia (2013, April 27)· | Wikipedia definition |

Elaborated by the author

# References


Azmaan, O., Giancarlo, D., & Tunmise O. (2011). Bitcoin advantages. *Stanford Computer Science Faculty and Staff*. Retrieved from http://www-cs-faculty.stanford.edu/~eroberts/cs181/projects/2010-11/DigitalCurrencies/advantages/index.html

Azmaan, O., Giancarlo, D., & Tunmise O. (2011). Bitcoin disadvantages. *Stanford Computer Science Faculty and Staff*. Retrieved from http://www-cs-faculty.stanford.edu/~eroberts/cs181/projects/2010-11/DigitalCurrencies/disadvantages/index.html

BBC. (2012, June 20). Facebook scraps its own Credits currency for apps. *Technology News*. Retrieved from http://www.bbc.co.uk/news/technology-18519921

Bishop, R. (2012, December 7). Bitcoin-Central approved to operate as actual bank, end of the world clearly nigh. *Geekosystem*. Retrieved from http://www.geekosystem.com/bitcoin-bank-licensed/

Bishop, M., & Green, M. (2012). *In gold we trust? The future of money in an age of uncertainty*. New York: The Economist [e-reader].
Boswell, R. (2012, April). Mint promotes digital-chip currency for penniless future. *Technology News at Canada.com*. Retrieved from http://www.canada.com/technology/Mint+promotes+digital+chip+currency+penniless+future/6418545/story.html
Burelli, F., Chua K., Alty, H., Morris, C., Rothkopf, M., Rofagha, M., et al. (2011). *Capturing the micropayments opportunity*. Value Partners Management Consulting Limited, Value Partners. Courtesy of Value Partners, received on July 18th 2012. Retrieved from http://www.valuepartners.com/downloads/PDF_Comunicati/Perspective/estrattomicropayments(1).pdf
Capie, F. H., Tsomocos, D. P., & Wood, G. E. (2003). *E-barter versus fiat money: will central banks survive?* (Working Paper, 197). Bank of England. Retrieved from http://www.bankofengland.co.uk/publications/Documents/workingpapers/wp197.pdf
Carroll, R. (2014, Friday 4). Tim Draper: The Bitcoin auction winner who wants to split California in six. *The Guardian*. Retrieved from http://www.theguardian.com/technology/2014/jul/04/tim-draper-bitcoin-auction-sillicon-valley-california
Castronova, E. (2001). *Virtual worlds: A first-hand account of market and society on the cyberian frontier* (CESifo Working Paper Series, 618). Retrieved from http://papers.ssrn.com/sol3/papers.cfm? abstract_id=294828
Castronova, E. (2003, February). *Theory of the avatar* (CESifo Working Paper Series, 863). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=385103
Castronova, E. (2007, October). Arden slows down, takes breather. *Terra Nova-Blogs*. Retrieved from http://terranova.blogs.com/terra_nova/2007/10/arden-slows-dow.html
Castronova, E. (2008). *A test of the law of demand in a virtual world: Exploring the petri dish approach to social science* (CESifo Working Paper Series, 2355). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1173642
Castronova, E. (2008, July). Arden: Final results. *Terra Nova-Blogs*. Retrieved from http://terranova.blogs.com/terra_nova/2008/07/arden-final-res.html#more
Castronova, E. (2010). On money and magic. *Journal of Virtual Worlds Research, 2*(4), 4–6. Retrieved from http://journals.tdl.org/jvwr/index.php/jvwr/article/view/861/626.
Champ, B., Freeman, S., & Haslag, J. (2011). *Modeling monetary economies* (3rd ed.). Cambridge: Cambridge University Press.
Cohen, N. (2011, July). Speed bumps on the road to virtual cash. *The New York Times*. Retrieved from http://www.nytimes.com/2011/07/04/business/media/04link.html?pagewanted=all
Costa, C., & De Grauwe, P. (2001). *Monetary policy in a cashless society*. SUERF Meeting, Brussels, October 25–27, 2001. Retrieved from http://www.econ.kuleuven.be/ew/academic/intecon/Degrauwe/PDG-papers/Work_in_progress_Presentations/cashless.pdf
Eldon, E. (2011, December). US virtual goods market to hit $2.9 billion in 2012, with facebook games maturing, mobile booming. *Technology Bits Blog NY Times*. Retrieved from http://techcrunch.com/2011/12/07/us-virtual-goods-market-to-hit-2-9-billion-in-2012-with-facebook-games-maturing-mobile-booming/
Erb, C. B., & Harvey, C. R. (2013). *The golden dilemma* (National Bureau of Economic Research (NBER) Working Papers, 18706). Retrieved from http://www.nber.org/papers/w18706
European Central Bank. (2012, October). *Virtual currency schemes*. Frankfurt am Main, HE: European Central Bank. Retrieved from http://www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf
Farmer, R. E. A. (2002). *Macroeconomics of self-fulfilling prophecies* (2nd ed.). Cambridge, MA: MIT Press.
Freedman, C. (2008). Payments systems and central banks: Where are we now and where will e-payments take us? In A. G. Haldane, S. Millard, & V. Saporta (Eds.), *The future of the payment systems* (pp. 255–261). Abingdon: Routledge.
Freeman, S. (1996a). Clearinghouse banks and banknote over-issue. *Journal of Monetary Economics, 38*(1), 101–115.

Freeman, S. (1996b). The payments system, liquidity and rediscounting. *The American Economic Review, 86*, 1126–1138.

Fuller, C. (2014, March 3). Bitcoin exchange MtGox CEO Karpeles faces lawsuit over bankruptcy; Personal finances targeted in class-action case. *International Business Times*. Retrieved from http://www.ibtimes.com/bitcoin-exchange-mtgox-ceo-karpeles-faces-lawsuit-over-bankruptcy-personal-finances-targeted-class

Fuloria, P. (2012, June 19). Introducing subscriptions and local currency pricing. *Facebook developers*. Retrieved from http://developers.facebook.com/blog/post/2012/06/19/introducing-subscriptions-and-local-currency-pricing/

Glaser, M. (2010, March). PayPal hopes to lure publishers to its micropayment system. *Mediashift*. Retrieved from http://www.pbs.org/mediashift/2010/03/paypal-hopes-to-lure-publishers-to-its-micropayment-system085.html

Glenbrook Partners. (2011). *Digital goods, virtual currencies, and social networks*. 2011 Payments Conference, Federal Reserve Bank of Chicago. Retrieved from http://www.chicagofed.org/digital_assets/others/events/2011/payments/mccune_0520_845.pdf

Goldsbury, C. R. (2012, February). Virtual currencies—where next? *Pragilematic*. Retrieved from http://anagilestory.com/2012/02/01/virtual-currencies-where-next/

Green, J. (2012, January). PayNearMe to go mobile to expand its cash-pay service. *American Banker*. Retrieved from http://www.americanbanker.com/issues/177_14/paynearme-mobile-progreso-cash-online-payments-1045920-1.html

Hansen, J. D., Soderquist, K., & Edwards, S. (2010, April 8). *Virtual currencies: Real legal issues for interactive entertainment companies*. IE Roundtable, Perkins Coie Lawyers. Retrieved from http://www.perkinscoie.com/files/upload/IE_2010_04_Roundtable-VirtualCurrency.pdf

Hayek, F. (1978). *Denationalisation of money: An analysis of the theory and practice of concurrent currencies* (3rd ed.). London: The Institute of Economic Affairs.

Helft, M. (2010, September). Facebook hopes credits make dollars. *Technology News, New York Times*. Retrieved from http://www.nytimes.com/2010/09/23/technology/23facebook.html?_r=1

Helft, M. (2011, April). Facebook is latest rival to Groupon and LivingSocial. *Technology—Bits Blog, The New York Times*. Retrieved from http://bits.blogs.nytimes.com/2011/04/25/facebook-is-latest-rival-to-groupon-livingsocial-facebook/

Hernandez-Verme, P. L., Huang, H., & Whinston, A. B. (2004a). Private electronic money, fiat money and the micropayment systems. *mimeo*.

Hernandez-Verme, P. L., Huang, H., & Whinston, A. B. (2004b). *Private electronic money, fiat money and the payments systems* (Department of Economics and Finance of the University of Guanajuato Working Papers, C200902). Retrieved from http://economia.ugto.org/WorkingPapers/EC200902.pdf

Hill, K. (2014, January 16). The feds are ready to sell $25 million of bitcoin seized from the Silk Road. *Forbes*. Retrieved from http://www.forbes.com/sites/kashmirhill/2014/01/16/the-feds-are-ready-to-sell-the-silk-road-bitcoin-kind-of/

Hudson, C. E. (2013, February 9). Amazon coins are steroids for the Amazon appstore. *TechCrunch*. Retrieved from http://techcrunch.com/2013/02/09/amazon-coins-are-steroids-for-the-amazon-appstore/

Infosecurity. (2011, March). Visa takes on PayPal with secure P2P micropayments service. *Infosecurity News*. Retrieved from http://www.infosecurity-magazine.com/view/16890/visa-takes-on-paypal-with-secure-p2p-micropayments-service/

Irwin, D., Chase, J., Grit, L., & Yumerefendi, A. (2005). *Self-recharging virtual currency*. Proceedings of the 2005 ACM SIGCOMM Workshop on Economics of Peer-to-Peer Systems, Philadelphia, PA. Retrieved from http://www.eecs.harvard.edu/~chaki/bib/papers/cereus-p2pecon05.pdf

Jordan, A. (2009, September). The currency revolution. *Wall Street Journal Blogs*. Retrieved from http://blogs.wsj.com/economics/2009/09/09/the-currency-revolution/

Kee, E. (2012, June 19). Facebook Credits to end up as real currency. *Ubergizmo*. Retrieved from http://www.ubergizmo.com/2012/06/facebook-credits-to-end-up-as-real-currency/

Leber, J. (2012, March). American Express looks beyond credit cards. *Business Impact: The Future of Money*, *Technology Review*, pp. 18–19.

Lowenthal, T. (2011, June 8). Bitcoin: Inside the encrypted, peer-to-peer digital currency. *Ars Technica*. Retrieved from http://arstechnica.com/tech-policy/2011/06/bitcoin-inside-the-encrypted-peer-to-peer-currency/

Luhmann, N. (2000). Familiarity, confidence, trust: Problems and alternatives. In D. Gambetta (Ed.), *Trust: Making and breaking cooperative relations (electronic edition)* (pp. 94–107). Oxford: Department of Sociology, University of Oxford. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.23.8075&rep=rep1&type=pdf&a=bi&pagenumber=1&w=100.

Mas, I. (2012, March). Me, my money, and my devices. *Business Impact: The Future of Money*, *Technology Review*, pp. 2–3.

Matthews, C. (2012, July 16). Will Amazon take over the world? *Time: Business & Money*. Retrieved from http://business.time.com/2012/07/16/will-amazon-take-over-the-world/

Meacham, G. (2011, June). Ven: The green digital currency. *D-Build*. Retrieved from http://d-build.org/blog/?p=2597

Metz, R. (2013, February 5). Could Amazon's virtual currency buy you a coffeemaker someday? *Technology Review*. Retrieved from http://www.technologyreview.com/news/510876/could-amazons-virtual-currency-buy-you-a-coffeemaker-someday/

Miemis, V. (2011, June). Ven: A digital currency designed for environmental sustainability. *Emergent by design*. Retrieved from http://emergentbydesign.com/2011/06/24/ven-a-digital-currency-designed-for-environmental-sustainability/

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. Retrieved from http://bitcoin.org/bitcoin.pdf

Pontin, J. (2011, March/April). The new money. *Technology Review*. Retrieved from http://www.technologyreview.com/featuredstory/422785/the-new-money/

Rochet, J. C., & Tirole, J. (2006). Two-sided markets: A progress report. *RAND Journal of Economics, 37*(3), 645–667. Retrieved from http://www.jstor.org/discover/10.2307/25046265?uid=3738664&uid=2&uid=4&sid=21102680592067.

Rolnick, A. J., Smith, B. D., & Weber, W. E. (1998). Lessons from a laissez-faire payment system: The Suffolk banking system (1825-58). *Federal Reserve Bank of Minneapolis Quarterly Review, 22*(3), 11–21. Retrieved from http://www.minneapolisfed.org/research/qr/qr2232.pdf.

Rolnick, A. J., & Weber, W. E. (1988). *Explaining the demand for free bank notes*. Minneapolis, MN: Federal Reserve Bank of Minneapolis. Retrieved from http://minneapolisfed.org/research/sr/sr97.pdf

Salomon, M., & Soudoplatoff, S. (2010). Why virtual world economies matter. *Journal of Virtual Worlds Research, 2*(4), 3–14. Retrieved from http://academia.edu/1014679/Why_Virtual_World_Economies_Matter.

Sandqvist, U., & Zackariasson, P. (2010). *The dematerialisation and democratisation of currencies: A historical description of currencies and how the physical has been replaced with the virtual*. Unpublished manuscript. Retrieved from http://www.academia.edu/767584/The_Dematerialisation_and_Democratisation_of_Currencies_a_historical_description_of_currencies_and_how_the_physical_has_been_replaced_with_the_virtual

Schenker, J. L. (2012, January 23). The future of money. *Informilo*. Retrieved from http://www.informilo.com/20120123/future-money-488

Schmitz, S. W. (2008). Will central banking survive electronic money? In A. G. Haldane, S. Millard, & V. Saporta (Eds.), *The future of the payment systems* (pp. 233–254). Abingdon: Routledge.

Schreft, S. L. (2000, April). *Private money, settlement, and discounts: A comment* (Federal Reserve Bank of Kansas City Working paper 00-01). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=271810

See-To, E. W. K., Jaisingh, J., & Tam, K. Y. (2007). Analysis of electronic micro-payment market. *Journal of Electronic Commerce Research, 8*(1), 63–83. Retrieved from http://eprints.lancs.ac.uk/48862/.

Simonite, T. (2012, March). Bitcoin seeks new life in Africa. *Business Impact: The Future of Money*, *Technology Review*, p. 14.

Smith, C. (2012, June 20). Facebook Credits to be replaced with real "local currencies." *TechRadar*. Retrieved from http://www.techradar.com/news/internet/web/facebook-credits-to-be-replaced-with-real-local-currencies-1086294

Smith, B. D., & Weber, W. E. (1998). *Private money creation and the Suffolk banking system* (Working paper). Research Department, Federal Reserve Bank of Minneapolis. Retrieved from http://www.minneapolisfed.org/research/wp/wp591.pdf

Stalnaker, S. (2012, January). The rise of private money. *Cayman Financial Review*. Retrieved from http://www.compasscayman.com/cfr/2012/01/11/The-Rise-of-Private-Money/

Stalnaker, S. (2012, August). E-mail correspondence with the authors.

Svensson, P. (2009, March). Online game gets real-world banking license. *The Sydney Morning Herald*. Retrieved from http://www.smh.com.au/technology/biz-tech/online-game-gets-realworld-banking-licence-20090615-c9ia.html#ixzz1ziEQn8mX

Takahashi, D. (2010, July 21). About 75% of online game fans have bought virtual goods, survey finds. *VentureBeat*. Retrieved from http://venturebeat.com/2010/07/21/about-75-percent-of-online-users-have-bought-virtual-goods-survey-finds/#k6DJmhHBPsQdPgOs.99

Talbot, D. (2012, March). Battle of the electronic wallets. *Business Impact: The Future of Money*, *Technology Review*, pp. 11–12.

Temzelides, T., & Williamson, S. D. (2001). Private money, settlement, and discounts. *Carnegie Rochester Conference Series on Public Policy, 54*, 85–108. Retrieved from http://www.artsci.wustl.edu/~swilliam/papers/carnroch01.pdf.

Thompson, S. (2011, July). Why Zong and PayPal are the perfect match. *The PayPal Blog*. Retrieved from https://www.thepaypalblog.com/2011/07/why-zong-and-paypal-are-the-perfect-match/

Valdes-Benavides, R. A., & Hernandez-Verme, P. L. (2014). Virtual currencies, micropayments and monetary policy: Where are we coming from and where does the industry stand? *Journal for Virtual Worlds Research, 7*(3), 1–10. Retrieved from https://jvwr-ojs-utexas.tdl.org/jvwr/index.php/jvwr/article/view/7064/6346

Wallace, B. (2011, November). The rise and fall of Bitcoin. *Wired Magazine*. Retrieved from http://www.wired.com/magazine/2011/11/mf_bitcoin/

Walsh, I. (2009, August). 7 benefits of a virtual currency. *Ivan Walsh*. Retrieved from http://www.ivanwalsh.com/business-development/7-benefits-of-a-virtual-currency/

Wikipedia. (2013, April 27). *Double spending*. Retrieved from http://en.wikipedia.org/wiki/Double-spending

Williamson, S. D. (1999). Private money. *Journal of Money, Credit, and Banking, 31*(3), 469–491.

Williamson, S. D. (2004). Limited participation, private money, and credit in a spatial model of money. *Economic Theory, 24*(4), 857–875. Retrieved from http://www.springerlink.com/content/6v8px15f2aqugnk7/?MUD=MP.

Windh, J. (2011). *Surveying a rapidly changing landscape*. Federal Reserve Bank of Atlanta. Retrieved from http://www.frbatlanta.org/documents/rprf/rprf_pubs/110815_wp.pdf

Wolman, D. (2012). *The end of money: Counterfeiters, preachers, techies, dreamers- and the coming cashless society*. Boston: Da Capo.

Yamaguchi, H. (2004). *An analysis of virtual currencies in online games*. The Japan Center for International Finance. Social Science Research Institute, International Christian University. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=544422

## *List of Websites Consulted*

Amazon Developer Services: http://developer.amazon.com/
Avios: http://www.avios.com/country-selection#gb
Bank of England: http://www.bankofengland.co.uk/
Bitcoin-Central: https://bitcoin-central.net/
Bitcoin charts: http://bitcoincharts.com/
Bitcoin: http://bitcoin.org/
Bitcoin Wiki: https://en.bitcoin.it/wiki/Main_Page
Dwolla: https://www.dwolla.com/
Entropia universe: http://www.entropiauniverse.com/
Financial Services Authority (FSA): http://www.fsa.gov.uk/
First Meta Exchange: http://firstmetaexchange.com/home
Gaming Surplus: http://www.gamingsurplus.com/#
Google Checkout: https://checkout.google.com/seller/fees.html
Hub Culture: http://www.hubculture.com/
Iberia: http://www.iberia.com/
InvestingAnswers: http://www.investinganswers.com/
Payclick: https://www.payclick.com.au/
PayNearMe: http://www.paynearme.com/
PayPal Developer Central: https://cms.paypal.com/us/cgi-bin/?cmd=_render-content&content_ID=developer/home
PayPal: www.paypal.com
PC Magazine (PCMAG): http://www.pcmag.com/
Plus500: http://www.plus500.nl/
Ripplepay: https://ripplepay.com/
Second Life: http://secondlife.com/
Site 12: Glenbrook Partners: http://www.glenbrook.com/
The Computer Language Company Inc.: http://www.computerlanguage.com/
The Virtual World Exchange (VirWox): https://www.virwox.com/
Ven: http://www.vencurrency.com/
Webopedia: www.webopedia.com
Wikipedia: http://en.wikipedia.org/wiki/Main_Page
Xchange4ls: http://www.xchange4ls.com
Zong: http://www.zong.com/

# Privacy in Virtual Worlds: A US Perspective to a Global Concern

**Jeannie Pridmore and John Overocker**

*Y'know, watching government regulators trying to keep up with the world is my favorite sport.*
(Stevenson, 1992: Snow Crash)

## 1 Introduction

In the first decade of the twenty-first century the number of people connected to the Internet increased from 350 million in 2001 to more than 2 billion in 2010. By 2025, the majority of the world's population, the majority of eight billion people, will be connected to the Internet (Schmidt & Cohen, 2013).

The promise of exponential growth along with technology improvements such as increases in immersion and sensory reality unleashes the possibility that VW could make online experiences as sensuously rich as the physical world. Or perhaps VW could produce an environment that surpasses the real world because of the superhuman senses and abilities that are embedded within them such as flying, walking through walls, and 1 day being able to experience all five senses through the VW.

As this space grows larger, VW will allow an increasing amount of people to live their lives by blending their real world life with their virtual life in a way that could erase the differences between the two completely. The blending of virtual lives and real lives raises questions of how privacy rights should be applied in VW?

The basic conceptions of a particularized right to privacy could be said to have existed for centuries. The argument could be made that the concept of ordered liberty would be impossible without the implied right of privacy. Nevertheless, the first significant mention of the "Right to Privacy" was a landmark Law Review Article authored by Justice Louise Brandeis and Samuel Warren in 1890.

Justice Brandeis considered privacy as the "most comprehensive of rights and the right most valued by civilized men (Brandeis, 1928)." In 1986, Mason predicted

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that the advent and use of Information and Communication Technology (ICT) would lead to four major concerns about the use of information: (1) Privacy, (2) Accuracy, (3) Property, and (4) Accessibility (Bélanger & Crossler, 2011). Since information often flows based on what is technologically possible rather than on what is socially or legally acceptable (Sundquist, 2012), privacy in particular has been a subject of increasing concern over the last few years for both individuals and organizations. In addition, Erik Snowden's revelations about the extent to which the United States' National Security Agency (NSA) has infiltrated both foreign and domestic organizations (governmental and non-governmental,) the Internet and the ability to protect the information we transfer and store on it have become a topic of international interest. It had been estimated that the NSA has the ability to intercept and download electronic communications equivalent to the contents of the Library of Congress every 6 hours (Mayer, 2011).

A recent survey showed that one in four young adults have exposed things through ICT that they fear could be used against them when it comes to employment, and among 18–34-year-old ICT users, 29 % say they feared that their photos, comments, or other personal information could come back to hurt them—either by causing a prospective employer to turn them down for a job, or by giving a current employer a reason to fire them (Croteau, 2013).

While individuals believe they should protect and control their personal information online (Deloitte Touche LLP & Ponemon Institute, 2007), people are posting, disclosing, and living out their lives online at ever increasing rates. This creates an enormous amount of personal data that are easily monitored and stored. Thereafter, data that was not intended to be public are, in some cases, accessed by other individuals, organizations, and governments.

Moreover, most of the basic business models of some of the largest companies operating online revolve exclusively around the collection and cultivation of this information. Most consumers operate under the misconception that they are the customers of their e-mail provider or social networking sight. The sobering reality is that the average "consumer" is in fact the product.

These companies provide services for free to the consumer and in turn collect information, which can be sold to third parties or handed over to governments. This exchange is often if not exclusively done without the knowledge of the "User."

The debate between privacy and security, as well as the trade-off between free or inexpensive services versus protection of private information will only heat up as more information is transferred from the Physical World (PW) to the VW for storage and transmittal. While economic theory suggests people have an ability to process the stream of privacy threats and trade-offs in the virtual world, people simply cannot be expected to navigate this uncertain terrain on their own (Acquisti & Grossklags, 2005). The lack of regulatory action and the growth of technology allows for potentially more privacy violations on a faster and larger scale.

VW are not lawless; however, VW technology presents new and unique situations that do not fit neatly into current legal frameworks (Nelson, 2011) or with other online privacy issues. The law that is applied is ill-fitted and in some situations illogical (Chambers-Jones, 2013). Overall, VW are under-regulated and deserve full and objective consideration in terms of privacy. They should not be grouped with the other ICT. The focus of this chapter is twofold.

1. Explain why VW should be considered separate from other ICT.
2. Grasp the current state of privacy rights for VW users in the US.

In conclusion, critical issues are identified that needs to be addressed in future research projects.

## 2 Virtual Worlds

The technology used in VW can be seen as another layer of coding that exists within the Internet. VW began as multi-user dungeons (MUD) and MUD object oriented (MOO), which were early text-based multi-user environments that combined role-playing with social chat rooms. From these early proto-ancestors evolved the graphically complex and highly immersive massive multiplayer online games (MMORPG) that serve as today's VW.

Today, VW are not just for game play. They provide a platform for users to explore, work, educate, and research. Users, in their virtual form as avatars, can wander around and experiment in an unstructured goal free environment or engage in purposeful activities.

For example, in Second Life, users in the form of an avatar can spend the day visiting Paris, flying over the ocean, relaxing on a secluded beach, or build their own virtual property like houses, cities, clubs, or a business store front in which virtual goods can be exchanged for real money.

Second Life avatars, if their users are so inclined, can even engage in virtual sexual activity or violence (Blitz, 2009). While some might argue that these virtual acts or virtual properties mean nothing in the real world, real world harm, either physical or financial, could be inflicted through the use of a VW.

In addition, VW allow for the PW and the VW to interchange. For example, some VW allow business employees to begin a conference call in the real world, and then continue it in the VW where the avatars cannot only share ideas but can also explore business models in a 3D space (Blitz, 2009). VW are thus an expansion of the quasi-physical world and should reflect the social norms and cultural of their society.

A vast amount of personal information can be recorded, stored, and analyzed in VW in a way that is simply not possible in the PW. VW technology has been specifically developed to store and analyze everything that its users do, so the VW can adapt around what the user is doing or has done. This information includes body movements, facial expressions, the people they interact with, what the interaction was about, the times the interaction took place, and consumer preferences.

These records can be connected to specific users and can sometimes be connected to their physical self. In addition, users who work or play in VW tend to be connected for several hours every day because of the immersive nature of

VW. This means much more data can be collected than with other ICT along with an easier and usually more accurate way of connecting the VW avatar with the real life person.

When creating a VW account, there is usually no process or procedure to verify the identity of the individual who is creating the account. Using someone else's identity to create an account and an avatar is very easy. The avatar identity could be completely fabricated, or it could be an entity using it to spy on others. Someone could a fake identity or steal a person's identity to purposefully or inadvertently do harm.

VW technology can also enable other individuals to spy on users without them ever knowing. This means that someone can collect and store information about users without that person being aware of it or without them being a willing subject. Furthermore, users have a level of anonymity when living as an avatar in a VW. This could lead to users disclosing more personal information than in other virtual environments.

Lastly, user driven content is another reason why VW are different than other ICT. Users build houses and businesses were they live and conduct business as if they were in the real world. Avatars can have families and dogs. They can watch movies and go on dates. Businesses create virtual goods which can be sold. Some individuals have even developed cities for their avatar and other avatars to live inside. Many real world universities and organizations conduct daily activities through VW. Users and organizations are constantly creating and adding to the VW in which they live and work.

Therefore, today's VW pose new and specific privacy concerns that are at times far greater than those arising in other ICT interactions. It is necessary to investigate the possible issues that affect privacy in VW. Zarsky (2006) identified two basic categories.

1. Privacy concerns that result from moving personal information between the VW and the physical world.
2. Privacy concerns that pertain to the collection, analysis and use of personal information exclusively within the VW.

The various forms of privacy concerns depend on the level of access to the flow of personal information available in VW. VW owners and their business affiliates have easy access to the entire scope of data described above. Using this data an overall profile of the user could be very accurately constructed as well as easily being linked to their real life identity.

## 3 The Right to Privacy in the United States

Before discussing privacy in VW, the legality of privacy in the US needs to be explained. The right to privacy in the United States is far too broad a topic to be tackled in one paper.

There is, to a certain extent, even a debate as to whether a right to privacy exists in the United States. *See Griswold v. Connecticut,* 381 U.S. 479 (1965) (*J. Black dissenting*.) In which Justice Black makes the case that there are no specific protections of a citizen's privacy only instances when privacy protection is a peripheral effect of the enforcement of other rights. The emergence of the right to privacy is of very recent origins (Rubenfeld, 1989). The fact that personal information is now much more of a commodity (more so than in 1890, or 1990, for that matter), may require privacy rights to be examined more as individual property. However, for the purposes of this chapter, the writers take the view that a right to privacy does exist, (*J. Goldberg concurring*).

This chapter will focus primarily on the Expectation of Privacy. This Expectation, which varies from place and situation, is the method by which the Courts determine Government action as reasonable under the protection of the Fourth Amendment.[1] The right to privacy protects an individual's right to be protected from unreasonable or offensive intrusion into their private affairs and concerns.

This right protects both physical privacy and other intrusions, such as the prevention of eavesdropping, restrictions on persistent, unwanted telephone calls, and prying into some forms of personal records. Privacy concerns generally involve at least one of three groups:

1. Government
2. Private Entities
3. Other Individuals

The US Constitution is a limiting document on the government's power and does not protect individual's privacy from the invasion by private citizens or entities. This holds true even if the information or property is later handed over to the government, unless the third party was operating under government instruction.

The Fourth Amendment states, "(t)he right of people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized." The Fourth Amendment protects against *unreasonable* search and seizure by the government.

A Seizure occurs when the government takes possession of items or detains people. A search is any intrusion by the government into something in which one has a reasonable expectation of privacy. Typically, eavesdropping or wiretapping of communications can constitute an illegal search and seizure. Though the Fourth Amendment only protects privacy from the government, it is important to highlight what it does and does not include in Table 1 (adapted from "Fourth Amendment", 2013). These details illustrate some of the complications in the right to privacy topic.

[1] The Supreme Court applied the Fourth Amendment to the individual states in the landmark case *Mapp v. Ohio*, 367 U.S. 643 (1961).

**Table 1** Fourth amendment privacy details

| Area | Protected | Not protected |
|---|---|---|
| Residences | Individuals in their homes have the highest expectation of privacy. | Conversations or other sounds inside a home that a person outside could hear, or odors that a passerby could smell without technological help to do so. If an individual opens their house to the public for a party, or some other public event, police officers could walk in posing as guests and look at or listen to whatever any of the other guests could. |
| Business premises | Individuals in their offices have a reasonable expectation of privacy if the office is not open to the public. | But if there is a part of the office where the public is allowed, like a reception area in the front, and if a police officer enters that part of the office as any other member of the public is allowed to, the officer can look at objects in plain view or listen to conversations there. |
| Trash | None | The things left outside a home at the edge of the property are unprotected by the Fourth Amendment. |
| Public places | Fourth Amendment challenges have been unsuccessfully brought against police officers using monitoring beepers to track a suspect's location in a public place, but it is unclear how those cases might apply to more pervasive remote monitoring, like using GPS or other cell phone location information to track a suspect's physical location. | Individuals have little to no privacy when in publications, movements, and conversations are knowingly exposed to the public—even if the individual thinks they are alone, they can be watched and recorded. |
| Infiltrators and undercover agents | None | Public meetings of community and political organizations, just like any other public places, are not private. Importantly, the threat of infiltrators exists in the virtual world as well as the physical world: for example, a police officer may pose as an online "friend" in order to access private social network profile. |
| Records stored by others | None | According to the US Supreme Court, information obtained and revealed by a third party to Government authorities is legal, even if the information was revealed on the assumption it would only be used by the third party for a limited time and for a specific purpose. |

(continued)

**Table 1** (continued)

| Area | Protected | Not protected |
|---|---|---|
| Opaque containers and packages | The contents of any opaque (not see-through) clothes or containers—laptops, pagers, cell phones and other electronic devices. | Anything exposed to the public is not protected. For example, if an individual in a coffee shop uses their laptop and an FBI agent sitting at the next table can see what is being written in an email; or if they open their backpack in a way that the FBI agent can see what is in the backpack. |
| Postal mail | If using the U.S. Postal Service, a package sent using First Class mail or above is protected, and a search warrant is needed to open the package. | There is no expectation of privacy in regard to the "to" and "from" addresses printed on the package, or what is written on a postcard. |
| Electronic surveillance | None | This is still being debated, but currently the US government can use electronic devices that are available to the public to monitor individuals without a warrant since this can be done without having to enter a private dwelling or use equipment not available to the public. |

Adapted from Fourth Amendment (2013)

Technology has added complexity to this topic, and is proving to be a substantial challenge for law makers to understand how technologies can and should be used in keeping with the right to privacy. The Supreme Court has offered little guidance by distinguishing between technology such as powerful binoculars that simply enhance an individual's senses and technology that creates new superhuman powers such as spyware. At times, they have relied on a distinction between sense enhancement and sense creation, a superficial distinction that fails to delineate when new surveillance technology is problematic.[2] *Katz v. United States,* 389 U.S. 347.

At other times, the Court has used language indicative of past Fourth Amendment doctrine requiring some sort of physical trespass in order to elicit the warrant requirement. The Court rejected that doctrine in *Katz*,[3] when it recognized that new technologies can make a private space versus public space impracticable to discern.

[2] *Katz v. United States*, 389 U.S. 347 (1967).

[3] In *Katz*, *supra*, the Supreme Court found that "the Fourth Amendment protects people, not places." Thus when a person enters a telephone booth, shuts the door, and makes a call, the government cannot record what that person says on the phone without a warrant. Even though the recording device was a public infrastructure phone when Katz shut the phone booth's door he reasonably expected no one would hear his conversation and it was protected from government intrusion.

In addition, the Courts have found that email enjoys the same level of protection as traditional mail.[4] However, the Court's failure to clearly explain the concerns about new technology and arbitrary use of language has confused the lower courts (Fairfield, 2009).

Since the Fourth Amendment applies to the government, the biggest concern for privacy of US citizens would be that of private organizations collecting, storing, and possibly selling personal data. However following the events of September 11, 2001, Congress passed the Patriot Act. The Patriot Act has been touted as necessary for law enforcement, providing the tools to prevent future acts of terror. Still, the Patriot Act gave the US government unprecedented authority to conduct surveillance. Thus privacy intrusions and government overreach have been a concern since its passage. The Patriot Act increases the government's surveillance powers in the following areas ("The US Patriot Act").

1. It increases the government's ability to look at an individual's records being held by third parties (Section 215).
2. It increases the government's ability to search without notice private property (Section 213).
3. It widens a narrow exception to the Fourth Amendment that had been created for the collection of foreign intelligence information (Section 218).
4. It extends the Fourth Amendment exception for spying and gathering "addressing" information about the origin and destination of communications, as opposed to the content (Section 214).

Government officials say that these powers are only invoked on people of interest or individuals who are suspected of wrong doing or are associated with known terrorists. However, critics have raised concerns about the possible over reach and unchecked government power to electronically track individuals with little or no evidence. These concerns are based the following issues:

1. The government no longer has to provide proof that the subjects of search orders are an "agent of a foreign power," previously this requirement protected Americans against abuse of this power.
2. The government does not have to provide reasonable suspicion or "probably cause" that the records are linked to criminal activity. The government simply has to make a broad assertion that the request is associated to an ongoing terrorism or foreign intelligence investigation.
3. Judicial oversight of these new powers is basically non-existent. The government must only certify to a judge that the requested search meets the statute's broad criteria, and the judge does not have the power to reject the request.

[4] *Randolph v. ING Life Insurance and Annuity Company*, 486 F.Supp.2d 1 (D.D.C., 2007) limits prospective liability where a loss or theft of personal data presents no more than a speculative threat of invasion of privacy, identify theft, or fraud. The case, which was resolved on a motion to dismiss, reflects the trend in U.S. case law that data controllers will not necessarily face liability for losing control of personal information if the loss did not cause actual harm.

4. Surveillance requests can be based partly on a person's First Amendment activities, such as Web sites visited, books read, or editorial letters written.
5. If a person or organization is forced to turn over records, they are prohibited from disclosing the search to anyone. As a result, the subjects of surveillance might never know that their personal records have been investigated by the government. That undermines an important check and balance of this power: the ability of individuals to contest illegitimate searches.

Again, the US government has continued to assure the public that these new powers are only utilized against those who have displayed concerning behaviour. However if the revelations of Eric Snowden are to be believed, they show the ease with which the government tracks and stores Internet activity. According to Mr Snowden, the NSA has operatives currently working undercover using fake online personas in VW such as Second Life, World of War Craft, and Eve for surveillance purposes.

In addition, Mr Snowden has informed the world that the US government has worked with major organizations such as Apple, Microsoft, and Google, to name but a few, to influence their encryption techniques. We believe this is, so far, to be the most concerning revelation. These are multi-national corporations with products at every corner of the globe, and the security of those products are suspect at best.

This leads many to wonder if the US government could have access to every Internet transaction that occurs without ever having to ask for that information from a third party. Thus, the US government could essentially have a back door into a number of Internet technologies in order to track anyone on Earth who us online they want.

So far, the information shared by Mr. Snowden have not been the catalyst for any changes to the Patriot Act, interpretation of the Fourth Amendment, or led to the creation of new laws. Still, Mr. Snowden has made the world aware of the extent to which the United States Security establishment has gone to track online activity and how few safeguards exist. Even President Obama during his 2013 end of the year press conference stated that a review of procedures and powers should take place in 2014, and that specific policy questions needed to be asked and answered.

For instance, should policies be based on what is possible for the government to do or what they should do? Notably, the President did not call for a stop to the practice of collecting information. President Obama merely suggested that the personal data collected should not be mined for information without just cause for US citizens. This "privacy protection" would not apply to international citizens.

From a third party, or private party, perspective, the Second Restatement of Torts (2000) states that an individual will be liable for unreasonable intrusion if he intentionally intruded upon the solicitude or seclusion of another and the intrusion is highly offensive to a reasonable person. This cause of action has been used primarily to prevent information gathering that reasonable people would find offensive. An individual may have a claim against a speaker who publicizes a private fact that does not have public concern and the disclosure of which a reasonable person would consider offensive.

In summary, privacy rights fall into three categories in the United States.

1. A citizen's right to privacy against government intrusion is guaranteed by the Fourth Amendment and Supreme Court cases such as Griswald v. Connecticut[5] (1965).
2. A person's right to privacy against the intrusions of private citizens is not guaranteed, but it is supported in most states through common-law developments (Prosser, 1960).
3. *Sui generis*[6] statutes emerge when legislatures seek to protect data in specific situations (Blanke, 2001).

*Sui* generis, or the so called right to be left alone, has been further divided into four categories (Prosser, 1960).

1. Unreasonable intrusion upon the seclusion of another
2. Appropriation of the other's name or likeness
3. Unreasonable publicity given to the other's private life
4. Publicity that unreasonably places the other in a false light before the public

These principles are currently the most relevant to privacy in VW.

## 4 The Right to Privacy in VW

What does all of this mean to the right to privacy in VW? Is there a reasonable expectation of privacy when in a VW? If there is, what is it? A reasonable expectation of privacy only exists if an individual can expect privacy, or if the expectation of privacy is one that society considers legitimate.

To date, courts have not reached a consensus on what constitutes a reasonable expectation of privacy online (Fairfield, 2009). A point of contention is whether reasonable expectations of privacy are determined by what the government can collect or what it should collect (Fairfield, 2009). It is important to note that an individual, either a private individual or a government agent, could join a VW with a fake identity and monitor whomever they wanted without ever obtaining a search warrant or having to reveal who they really are. Again, according to Mr Snowden, this has been going on for several years now.

[5] In *Griswold*, *supra,* the Court held that the right of privacy within marriage predated the Constitution. The ruling asserted that the First, Third, Fourth, and Ninth Amendments also protect a right to privacy.

[6] A law created by the legislature to protect intellectual property that might not otherwise be protected. See Black's Law Dictionary (8th Edition).

The Supreme Court has found there is no reasonable expectation of privacy for information an individual "knowingly exposed" to a third party—for example, bank records, telephone records, or possibly even VW records—even if it was intended for the third party to keep the information private (Fourth Amendment, 2013). By engaging in transactions in a VW, the Court contends, individuals are assuming risk that the third party will share that information with the government or other third parties as stated in the user agreement.

When an individual signs up for a VW and creates an avatar, normally they must agree to the terms of the VW owners. These agreements are typically referred to as End User License Agreements (EULA), Terms of Service (TOS), or simply set out in lesser documents such as Codes of Conduct and Reimbursement Polices (Lim, 2008). Many commentators criticize these contracts as being too one-sided and argue for the courts to acknowledge traditional common law rights (Cifrino, 2014).

An individual may "knowingly expose" more than they know or intend to due to the terms of the agreement. By signing this agreement users agree to the privacy terms the VW owners and operators. All of the data collected, stored, and analyzed are done with the user's permission. All rights are waivable thus this collection is probably not protected by the Fourth Amendment under current law. There may be privacy statutes that protect against the sharing of this information—some communications records receive special legal protection, for example—but there is likely no constitutional protection. Thus, if so inclined the government may easily obtain that information without the individual ever being notified.

The users of VW are bound by the rules put forth by the VW owners in the EULA, TOS, or Codes of Conduct and Reimbursement Polices. These agreements are lengthy and, complicated. With increasing frequency VW's require users waive significant rights before they may use their products. Some have argued that these agreements are not efficient, not legally secure, and give the VW owners all of the control (Roquilly, 2011).

It has long been said that the biggest lie told on the Internet today is "Yes, I have read and agree to the terms" (Finley, 2012). To illustrate how users are becoming aware of the one sided nature of these interactions, websites and even a Facebook page exist, dedicated to the topic of unfair, long, and confusing TOS agreements.

This is not to say that the Internet or VW are devoid of laws or regulation. The US currently uses a "3-E Approach" (**E**ducation, Targeted **E**nforcement, **E**xisting Legal Standards) in regard to online privacy. The US realizes the need for adaptation for online privacy due to the complications that arise from different technologies, different uses and different situations.

The "3-E Approach" presumes the impossibility of crafting a single, universal solution to online privacy concerns. It aims instead to create a flexible framework to help individuals cope with a world of rapidly evolving technological change and shifting social and market norms as they pertain to information privacy (Thierer, 2013). One problem with the "3-E Approach" is that most of the responsibility is on the user. As a possible result of this, no other countries seem to be taking the US' "3-E Approach" as a guide to online privacy. The European Union has drafted their own policy which seems to be having a more immediate global impact (Thierer, 2013).

Overall, there seems to be two main camps when it comes to how privacy rights should be set for VW. One camp believes privacy rights should be set by the "market" referred to as "separatists" (Chambers, 2012). This group believes that market pressures or industry pressures from users or society will force self-regulation that will ultimately create the best outcome.

The second camp believes privacy rights should be regulated by the government or "inclusionists" (Chambers, 2012). While education and user empowerment is important, some government regulation will be critical moving forward. It will be interesting to see what impact if any the Snowden revelations will have on privacy policies moving forward.

Given the diverse needs and use of VW technologies, no silver bullet, all in one solution is likely to be forthcoming. Both sides require scrutiny and consideration in order to develop privacy education for all users. This would include the importance of TOS, empowered users who understand how critical they are to the success of VW, and legal professionals who can impart upon law makers which privacy laws and rights are essential for online user protection.

## 5 The Future of Privacy in VW

Future debate and research is critical for the field on privacy rights in VW, and this debate needs to happen now not only from a US perspective but also as a global concern. People need to understand how the virtual world works and the regulations/laws that apply them in the virtual world. Even the European Network and Information Security Agency has stated that privacy is a major risk from Avatar identity theft and fraud to the amount of personal data being exchanged in the virtual world (Farahmand, Yadav, & Spafford, 2013).

Can a reasonable expectation of privacy ever exist for data in VW, and could this data ever be protected by the Fourth Amendment? How is the answer to the previous question affected by the fact that sometimes the data was "knowingly exposed" to a third party, other individuals, or to the public at large? To attempt to answer this question, three main areas of future research are put forth in Table 2.

### *5.1 Private Space Versus Public Space*

First it is critical to realize if a private space could ever exist in a VW. This is an important point in determining privacy rights in VW. Previous court cases have found phone calls on public pay phones are private conversations. Similarly, email is afforded the same protection as United States Postal Mail service. A logical conclusion could be that certain parts of VW might also be afforded such rights and

**Table 2** Future research areas

| | |
|---|---|
| Private space versus public space | (1) Could user driven content areas be seen as private spaces?<br>(2) If so, is there a level of privacy that someone could reasonably expect when entering a "private space" in a VW? |
| Online persona | (1) Since avatars are the virtual representation of a real person, could real life privacy laws be applicable? |
| Online persona and property rights | (1) Could privacy laws be the answer to virtual property theft?<br>(2) Could privacy laws be used to protect users' intellectual property rights? |
| Global privacy concerns | (1) Could privacy regulations exist on a global level? Would this be enough to ensure protection?<br>(2) Is there a market for privacy services to be bought on an individual basis worldwide? If so what would those services look like? |

protection. For example, if user driven content areas such as houses or business could be considered private property inside a VW, it is possible that the data exchanged in those areas could maintain the same rights as in the PW.

Since users can build and live in houses and run businesses in VW as well as being able to perform very personal private acts in VW, it could be argued that there is a reasonable expectation of privacy in specific situations even though the actions are being conducted online in a VW. In these situations, individuals probably have a sense of privacy, and that could be a very strong case for the right to privacy of the user while in a "private space" of a VW. This creates questions that need to be answered.

1. Could user driven content areas such as houses, businesses, etc. be seen as a "private space"?
2. If so, is there a level of privacy that someone could reasonably expect when entering a "private space" in a VW?

It is not easy to answer questions like these. First, there must be a discussion if it is possible to distinguish between a public and private space in VW? This has been a much debated topic. On one side of the debate, some have argued that VW are, in fact, public spaces as they represent the essence of public spaces (Oliver, 2002).

Others have argued that VW are not public spaces as they are carefully controlled with certain rules and regulations crafted by the owners of the VW environment (Taylor, 2002) and a large part of the success of a VW can be attributed to user driven content. In terms of corporate ownership, user driven content and intellectual property rights, VW and spaces contained in them could function as "private spaces".

A PW comparison of a VW could be similar to a shopping mall, meaning a private space that is often perceived as being a public space. However, if a person owns and operates a business space within the shopping mall, the only part of that business that is considered public is the area where the public is welcomed. Could this distinction also be made in a VW business? What about a house in real life?

Every individual has a right to privacy in their home. What about the right to privacy in a virtual house?

If these two situations can be interchanged between the VW and the physical world, then should the same privacy rights extend to the VW as it does to a real world? Further, since information in briefcases and backpacks carry privacy protections, why should virtual identities created with user driven content such as photos, email addresses, and correspondences not carry the same privacy rights?

For the user, the distinction between whether a VW space functions as a public space or as a "private space" could be an important factor in determining the expectation of privacy when living in a VW. Since Privacy is based on what is "reasonable" or what a "reasonable person" expects, it could be reasonable to poll people as to what they expect from both a US and global perspective. For now, users who lack a proper understanding of what "private spaces" or public spaces are in VW will continue to expose information that they otherwise would protect. After realizing the information has been revealed they may feel as if their privacy has been violated when in fact those protections did not exist or have been waived by the users. A more formal clarification or distinction between what public and private spaces will continue to be ambiguous until users of VW force the conversation with the VW owners and operators and possibly demand action to regulate on their behalf. Until then, users should take reasonable precautions and assume that their information is vulnerable.

## *5.2 Online Persona*

It has been suggested that the best way to protect VW users is through the concept of personhood or persona (Nelson, 2011). An online persona consists of an individual's attributes that identify them to a reasonable third party and is comprised of their name, signature, photograph, image, likeness, and voice (Kutler, 2011). Therefore, an online persona identifies a person to others (third parties, government entities, or private individuals) through email accounts and online identities such as VW avatars. Especially in VW where the avatar becomes an extension of the physical person's self from the formation of the avatar's interest and actives to their personal relationships (Blitz, 2009).

The online persona is an intangible, yet legally protectable asset (Kutler, 2011). However, avatars do not maintain the same online privacy rights as their physical selves do. From a government perspective, this could be explained by not having to physically infringe upon the person to collect the data. From the private third party perspective, the individual agreed to the terms of service by clicking the "I Agree" button. If it could be argued that the avatar is truly an extension of the physical person, then should the same privacy rights be extended to the avatar in a VW as they are applied to the individual in the physical world?

In addition, what if someone takes another person's name, builds a VW avatar, and lives in the VW as that other person. Even if the VW is contacted and this offense is covered in the VW TOS, what penalty is imparted for this invasion of persona and right to privacy? At best, the account will be removed, and the VW might be able to block that user from ever creating another account. Should that individual be held accountable in the real world? What if that person caused mental or physiological harm on the person whose identity they took in the real world? Given the connection between the online persona and the physical persona, it's hard not to understand that real world harm could be inflicted in this given scenario.

What if the fake account was created to steal virtual property from the user? It has been argued that privacy laws could be used as an efficient way to protect users against virtual property theft. Virtual property theft violates the persona of the VW user because it invades the private areas of the victim's identity and privacy (Nelson, 2011). One possible reason as to why privacy could be an efficient way to govern the theft of virtual property is that it is hard to assign value to virtual property, but it is much easier to understand the personal connection to the loss of property even if it is virtual property.

## *5.3 Privacy in VW: A Global Concern*

Since VW are global entities, it would be short sighted to consider it only from a US perspective and not discuss it as a global concern. As Eric Snowden has made everyone aware, now is the time to stand up for online privacy rights on a global level. Is it possible to create a code of privacy or a right to privacy on a global level? What would be or should be included in a global privacy policy?

Google has encouraged the UN to set global privacy rules since so much data is sent around the world to countries that do not have any privacy regulations (Johnson, 2007). The possibility that the UN might try to step in is causing opposition from many organizations and countries worldwide (Thierer, 2012). There are policy groups such as the Global Internet Policy Initiative (http://www.internetpolicy.net/) which is a non-profit organization that collects Internet policy information to help transitional countries develop policies such as privacy rights to protect their citizens.

Lastly, could the right to privacy be something people are willing to pay for on an individual level worldwide? Would someone be willing to pay $3 or $5 a month to ensure that their virtual information would not be tracked? Would or could these kinds of privacy services emerge if users demanded it? What would be included in services like this, and could they actually guarantee privacy on a global level? How would individual privacy compared to the public's right to know or information for the greater good be balanced? Is this possible? Some countries around the world are hoping this could be possible and could serve as a source of revenue (Thierer, 2012).

## 6 Conclusion

Currently privacy rights of VW users are set up and defined by the TOS of the VW. The argument is put forth that privacy rights in VW need to be reconsidered from a legal stance and a user rights perspective. This should be approached in two ways, from the VW users working with the VW to improve their rights in the TOS and improved government privacy regulation as called for by the VW community. As in the days of the Wild West, the law has been slow to make its way into the realm of VW. Privacy laws or the right to privacy is critical at this point in the development of VW for several reasons.

For one, technology is advancing so fast, it is important to begin this process today if there is any hope in being able to keep up with new technology as it is introduced. Secondly, with the global aspects of VW and the rise of the Internet population from developing countries VW may soon be experiencing a flood of users that may not share the same concept of privacy as most "Western" users because of cultural and legal differences. Setting the foundation for future growth in the definition of online privacy is a critical subject that needs to be addressed now. Without established standards in place this large influx of new users who may not be concerned or share the same concept of privacy could detrimentally impact the expansion and definition of privacy rights and protection to VW users.

## References

Acquisti, A., & Grossklags, J. (2005). Privacy and rationality in individual decision making. *IEEE Security and Privacy, 3*(1), 26–33.

Bélanger, F., & Crossler, R. E. (2011). Privacy in the digital age: A review of information privacy research in information systems. *MIS Quarterly, 35*(4), 1017–1042.

Blanke, J. M. (2001). Criminal invasion of privacy: A survey of computer crimes. *Jurimetrics Journal, 443*, 449–456.

Blitz, M. J. (2009). A first amendment for Second Life: What virtual worlds mean for the law of video games. *Vanderbilt Journal of Entertainment & Technology Law Journal, 11*, 779–822.

Brandeis, J. (1928). Olmstead v. United States, 277 U.S. 438, 478 (dissenting).

Chambers, C. (2012). Can you ever regulate the virtual world against economic crime? *Journal of International Commerical Law and Technology, 7*(4), 339–349.

Chambers-Jones, C. (2013). Virtual world financial crime: Legally flawed. *Law and Financial Markets Review, 7*(1), 48–56.

Cifrino, C. J. (2014). Virtual property, virtual rights: Why contract law, not property law, must be the governing paradigm in the law of virtual worlds. *Boston College Law Review, 55*(235), 235–264. http://lawdigitalcommons.bc.edu/bclr/vol55/iss1/7.

Croteau, M. (2013). *A quarter of young people have facebook or other social media postings they may later regret, says New FindLaw.com survey*. Retrieved from http://company.findlaw.com/press-center/2013/a-quarter-of-young-people-have-facebook-or-other-social-media-pos.html#sthash.49cjPJ1z.dpuf

Deloitte and Touche LLP, & Ponemon Institute LLC. (2007). *Enterprise@Risk: 2007 privacy & data protection survey*. Retrieved from http://www.deloitte.com/dtt/cda/doc/content/us_risk_s%26P_2007%20Privacy10Dec2007final.pdf

Fairfield, J. (2009). Escape into the Panopticon: Virtual worlds and the surveillance society. *The Yale Law Journal Pocket Part, 118*, 131–135.

Farahmand, F., Yadav, A., & Spafford, E. H. (2013). Risks and uncertainties in virtual worlds: An educators' perspective. *Journal of Computing in Higher Education, 25*(2), 49–67.

Finley, K. (2012). Putting an end to the biggest lie on the internet. *Tech Crunch*. Retrieved September 29, 2013, from http://techcrunch.com/2012/08/13/putting-an-end-to-the-biggest-lie-on-the-internet/

Fourth Amendment. (2013). Legal Information Institute, Cornell University of Law School. Retrieved August 1, 2013, from http://www.law.cornell.edu/wex/fourth_amendment

Griswold v. Connecticut (1965). 381 U.S. 479, pp. 483–484.

Johnson, B. (2007). Google urges UN to set global internet privacy rules. *The Guardian*. Retrieved from http://www.theguardian.com/technology/2007/sep/14/news.google

Katz v. United States. (1967). 389 U.S. 347, 358–359.

Kutler, N. (2011). Protecting your online you: A new approach to handling your online persona after death. *Berkeley Technology Law Journal, 26*, 1641–1668.

Lim, H. Y. F. (2008). Who monitors the monitor-virtual world governance and the failure of contract law remedies in virtual worlds. *Vanderbilt Journal Entertainment & Technology Law, 11*, 1053–1073.

Mayer, J. (2011, May 23). The secret sharer: Is Thomas Drake an enemy of the state? *New Yorker*, pp. 47–49.

Nelson, J. W. (2011). A virtual property solution: How privacy law can protect the citizens of virtual worlds. *Oklahoma City University Law Review, 36*, 395–420.

Oliver, J. H. (2002). The similar eye: Proxy life and public space in the MMORPG. In *Proceedings of the 2002 Computer Games and Digital Cultures Conference* (pp. 171–184).

Prosser, W. L. (1960). Privacy. *California Law Review, 48*(3), 383–423.

Restatement (Second) of Torts (2000) § 625C.

Roquilly, C. (2011). Control over virtual worlds by game companies: Issues and recommendations. *MIS Quarterly, 35*(3), 653–672.

Rubenfeld, J. (1989). The right of privacy. *Harvard Law Review, 102*(4), 737–807.

Schmidt, E., & Cohen, J. (2013). *The new digital age: Reshaping the future of people, nations and business*. New York: Knopf.

Stevenson, N. (1992). *Snow crash*. New York: Random House Digital.

Sundquist, M. (2012). Online privacy protection: Protecting privacy, the social contract, and the rule of law in the virtual world. *Regent University Law Review, 25*(153), 1–29.

Taylor, T. L. (2002). 'Whose game is this anyway?' Negotiating corporate ownership in a virtual world. In *Proceedings of the 2002 Computer Games and Digital Cultures Conference* (pp. 227–242).

The USA PATRIOT Act: Preserving life and liberty. Retrieved October 15, 2013, from http://www.justice.gov/archive/ll/highlights.htm

Thierer, A. (2012). *Does the internet need a global regulator?* Retrieved from http://www.forbes.com/sites/adamthierer/2012/05/06/does-the-internet-need-a-global-regulator/2/

Thierer, A. (2013). Privacy, security, and human dignity in the digital age: The pursuit of privacy in a world where information control is failing. *Harvard Journal of Law & Public Policy, 36*, 409–915.

Toney v. L'Oreal USA, Inc. (7th Cir. 2005). 406 F.3d 905, 908-09.

Zarsky, T. (2006). Privacy and data collection in virtual worlds. In J. M. Balkin & B. S. Noveck (Eds.), *State of play—Law, games and virtual worlds* (pp. 217–223). NY: NYU Press.

# Avatars and Behavioral Experiments: Methods for Controlled Quantitative Social Behavioral Research in Virtual Worlds

**Dimitrij (Mitja) Hmeljak and Robert L. Goldstone**

## Introduction

The computing infrastructures of 3D3C Worlds can support real-time, quantitatively controlled experiments for studying human group behavior. While there exist effective techniques for designing experiments and analyzing human group behavior in synthetic ad-hoc environments, there is under-exploited scope for controlled group experiments in virtual worlds, to facilitate the study of how groups of individuals behave under well-defined conditions when undertaking a specified task.

The goal of this chapter is to define the criteria and parameters for a software platform for behavioral experiments in 3D3C Worlds. To accomplish this goal, we start by providing a background introduction of social behavior research and related methods of study; we then present a review of relevant previous behavioral research studies in 3D3C Worlds, and we conclude by presenting our own experimental platform.

Virtual worlds "have great potential as sites for research in the social, behavioral, and economic sciences, as well as in human-centered computer science" (Bainbridge, 2007, p. 472). This chapter reviews examples of social behavioral research in virtual worlds, their methodologies and goals, such as studies of socio-economical trends, interpersonal communications between virtual world residents, automated survey studies, etc. The chapter contrasts various existing social behavioral research tools in virtual worlds with the goal of studying human group

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behavior as a complex system, specifically exploring how interacting groups of people create emergent organizations at a higher level than the individuals comprising such groups (Goldstone, Roberts, & Gureckis, 2008): the research goal is to conduct well controlled experiments on group behavior within an existing 3D3C World. This chapter further provides a synopsis of tested techniques that may be used to implement such experiments, highlighting those computational constraints imposed by 3D3C Worlds' infrastructures that may require a Resource-Limited Computing approach. The presented final design and implementation, our Group Behavior Virtual Platform implemented in the Second Life (SL) virtual world, secures advantages of both laboratory and real world field research. Like typical behavioral laboratory research, these studies are designed to carefully control the participants' environment, randomly assign participants to experimental conditions, and log moment-to-moment behaviors of the participants. Like field research, these studies recruit participants from their existing environment, in this case a virtual world, and the participants choose their own identity and are behaving in an environment with which they are familiar and comfortable.

Throughout the chapter, the term "Reference Studies" will refer to the studies pertaining to the specific research goal of studying human group behavior as a complex system, and the term "Reference Implementation" will refer to the design and implementation of our *Group Behavior Virtual Platform* that has been instrumental to conducting well controlled experiments on group behavior within an existing 3D3C World.

The sections comprising this chapter are shown in Fig. 1. Here is a brief overview of the organization:

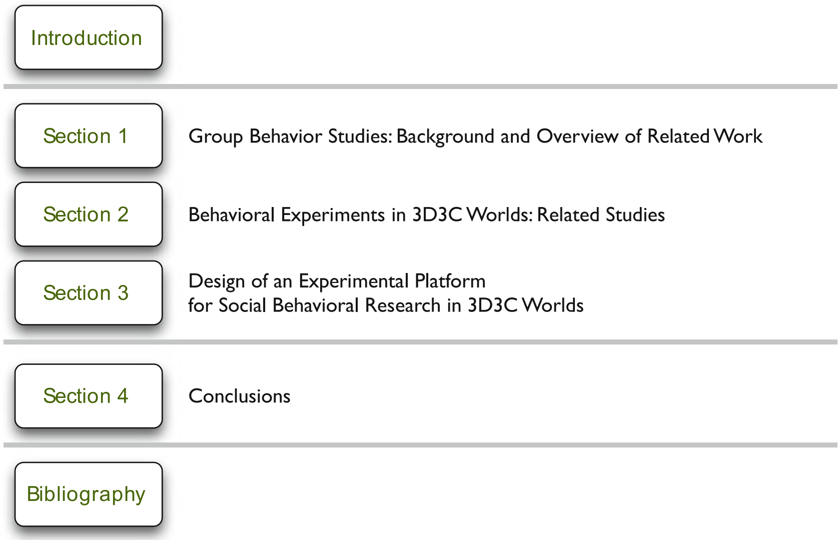



**Fig. 1** Organization of this chapter and layout of its sections

Section 1: Group Behavior Studies: Background and Overview of Related Work. The first section provides the background information necessary to understand the problem and its domain, by illustrating relevant concepts in social behavior research and related methods of study.

Section 2: Behavioral Experiments in 3D3C Worlds: Related Studies. This section includes a review of relevant previous studies in behavioral research in 3D3C Worlds, as well as the problem of supporting controlled quantitative experiments in 3D3C Worlds.

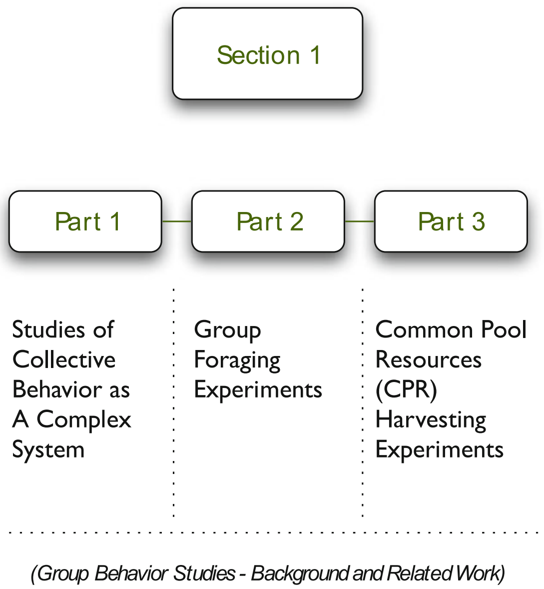
Section 3: Design of an Experimental Platform for Social Behavioral Research in 3D3C Worlds. This section covers techniques for designing an experimental infrastructure in a 3D3C World, detailing the various issues encountered in providing support for running quantitatively controlled real-time group experiments.

Section 4: Conclusions.

## 1 Group Behavior Studies: Background and Overview

Designing and running controlled and quantitative group behavior experiments in virtual worlds involves concepts and methods from disparate domains including social psychology, virtual reality, and resource-constrained computing. To familiarize the reader with the topics, this section introduces concepts relevant to the study of human group behavior in general, and experiments for studying emerging social patterns in particular. The parts comprising this section are shown in Fig. 2.

**Fig. 2** Organization of Sect. 1



Here is a brief overview of the organization: this section begins with an introduction to established methods in emergent group behavior studies—traditional controlled lab experiments, with in-person group participants, where patterns in group behavior are observed and measured for subsequent analysis. The section then presents two fundamental experiments from this category: the Group Foraging and the Common Pool Resources Harvesting experiments.

### *1.1 Studies of Collective Behavior as a Complex System*

Complex adaptive systems theory studies how a large number of interacting elements may lead to higher level properties emerging from lower level interactions acting as a form of decentralized, distributed processing. Examples range in nature from non-organic formations, to plant structures, to complex social structures in the animal world. Applications of mathematical and computational models become relevant to apparently dissimilar systems.

While cognitive science often focuses on studying the behavior of single individuals, the study of human group behavior as a complex system seeks understanding of how interacting groups of people may create emergent organizations at a higher level than the individuals comprising such groups.

Collective yet not intentionally coordinated actions of a large number of participating individuals can produce structures, architectures and group-level behaviors that are distinct from any individual's goals; as from Goldstone et al. (2008, p. 10): "Just as neurons interconnect in networks that create structured thoughts beyond the ken of any individual neuron, so people spontaneously organize themselves into groups to create emergent organizations that no individual may intend, comprehend, or even perceive."

Participants in group behavior studies are placed in dynamic and interactive simulations of real life situations, interacting in real-time while asked to solve a specific task. The goal is to scientifically observe and model how groups of people behave when their behavior depends on the behaviors of others around them. For example, in some of these experiments, individuals are asked to manage the growth of a resource available to the entire group, while simultaneously trying to maximize their own harvesting of the same resource. A problem faced by all mobile organisms is how to search their environment for resources. Animals forage their environment for food, web-users surf the internet for desired data, and businesses mine the land for valuable minerals (Goldstone & Ashpole, 2004). When groups of animals in natural settings forage for resources, each animal may be free to move between sources of food, yet food resources available to each individual are affected by other animals' foraging behavior as well as its own. Each individual's best strategy for gathering resources becomes more complex than the mere discovery of resource locations, because it is affected by other individuals' foraging strategies as well.

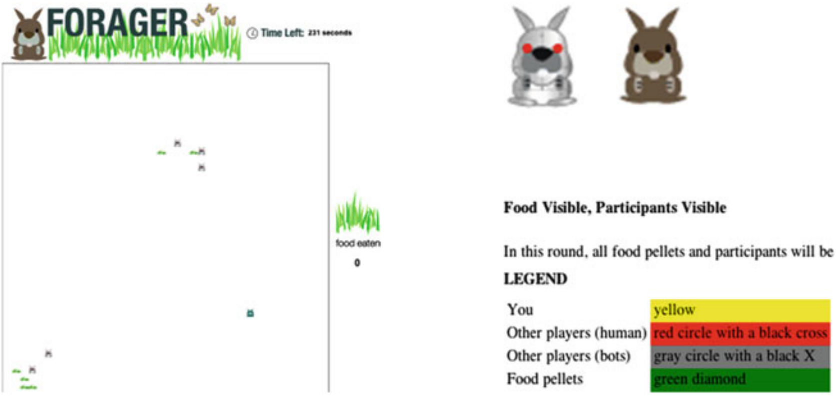



**Fig. 3** The Forager Game implemented as a Java applet

## *1.2 Group Foraging Experiments*

Experiments designed to study group foraging for resources are typically set in an environment where desirable virtual resources are provided for participants to collect. An experimental technique for studying human foraging behavior utilizes a stylized 2D computer game platform that allows many human participants to interact in real time within a common environment (Goldstone & Ashpole, 2004). The Forager Applet, an online game version of the same experimental platform, establishes the settings for a foraging group behavior experiment, where the goal of the game for each participant is to gather food pieces from a grid of squares, as in Fig. 3.

Resource pools can be created within this environment, and the experimental platform must track and record moment-by-moment exploitations of these resources by each human participant. The game can be run under a number of independently controlled conditions, such as resource distribution, user visibility, and food visibility.

## *1.3 Common Pool Resources (CPR) Harvesting Experiments*

In another example, as part of a larger project described in Janssen, Goldstone, Menczer, and Ostrom (2008) aimed at studying what causes individuals to invest in rule development, and which cognitive processes explain the ability of humans to craft new rules, experiments have been designed to study how a group of human subjects share a renewable resource, by implementing Common Pool Resource (CPR) Harvesting games. Here too, resources are created within a synthetic environment, and the experimental platform must track and record moment-by-moment

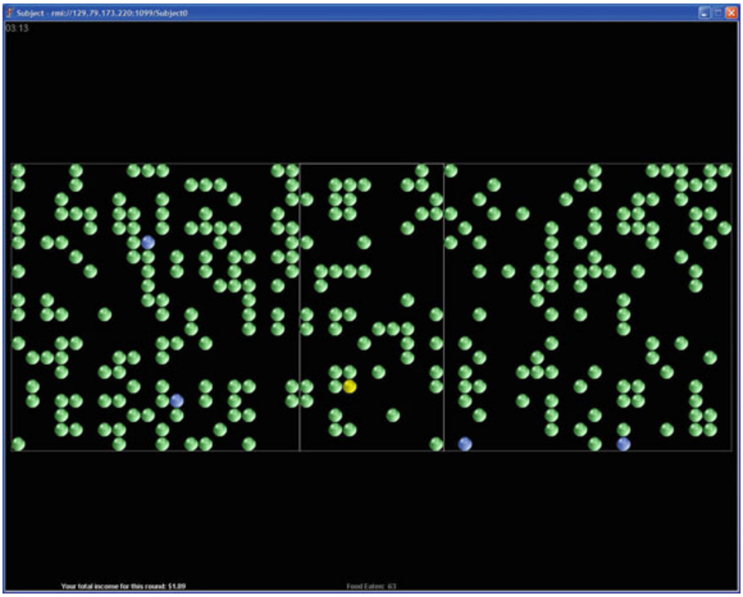



**Fig. 4** A screenshot from a 2D CPR Harvesting game experimental environment. Participants see themselves as represented by a *yellow dot*, other participants as *blue dots*, and food resources as *green dots*, while the *white lines* show property boundaries for the *yellow dot* (Credit: Janssen et al., 2008)

harvesting of these resources by each human participant. A screenshot from this 2D CPR Harvesting game experimental environment is shown in Fig. 4.

When studying the emergent behavior of groups of individuals, there are further advantages in following well-defined controlled quantitative experiments: these methodologies also allow for comparisons between experimental results in group behavior studies with agent-based computational models.

## 1.4 Data Analysis Methods

To collect data for subject behavior analysis of the studies presented above, a complete data snapshot of the synthetic environment needs to be sampled every few seconds. Recorded data has to include all participants' locations as (x, y) coordinates on the game grid, the number of resource units collected by each participant at that instant, and uncollected food pieces' (x, y) cell coordinates on the game grid. For each experiment run, groups are assigned to different experimental conditions related to the proportions in the food distribution between two resource pools, and visibility or invisibility of other participants and resources. Figure 5 shows how by computing the proportions of participants in the two pools

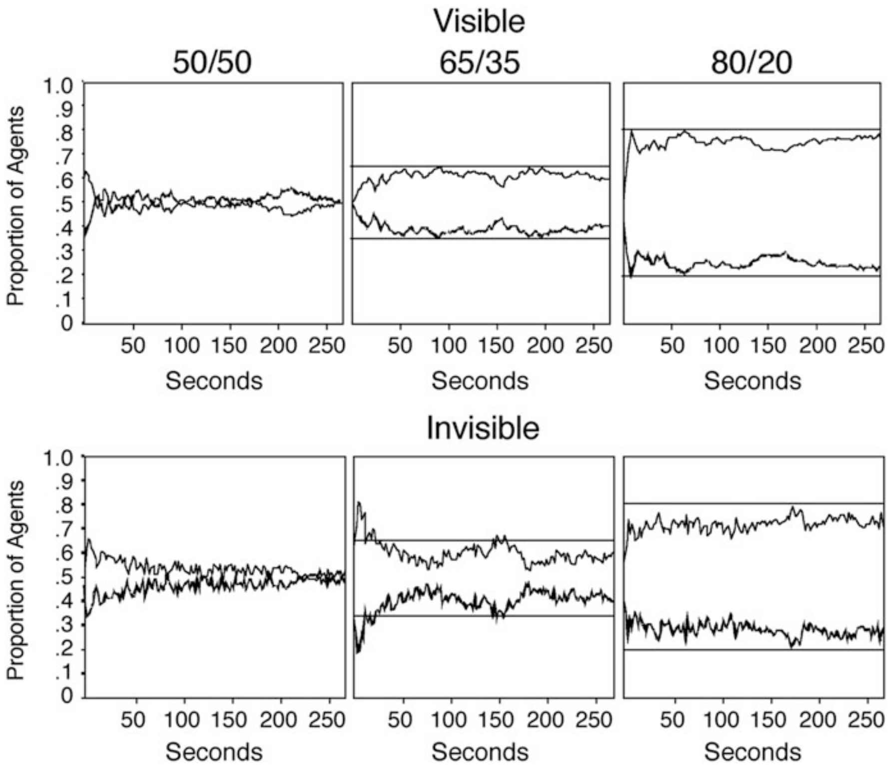



**Fig. 5** Dynamics of the distribution of foragers to resources: proportions of participants in two resource pools, broken down by the six conditions. (Credit: Goldstone & Ashpole, 2004). This figure shows the dynamics of the distribution of participants to resources in the Forager study, broken down by the six controlled conditions as from the experiment design. In this figure, the proportion of participants in two pools is plotted over time within a session. *Horizontal lines* indicate the proportions of participants that would match the distribution of food. Although the figure shows that the distribution of participants adjusted quickly, including the earliest time samples in the probability distribution estimate would lead to estimates that were inappropriately regressed toward the mean of 50 %. The figure also shows that the distribution of participants systematically undermatched the optimal probabilities. For example, in the 65/35 distribution of resources, the 65 % pool attracted an average of 60.6 % of the participants in the 50- to 270-s interval of the experiment

over time within a session, one can obtain the dynamics of the distribution of participants to resources during the session.

Analyzing the distribution of participants to that of food resources, one result was that groups approximate the distribution of resources, but systematically undermatch them, as shown in Goldstone, Roberts, and Roberts (2005): for example, if resources are distributed in a 20/80 fashion, the actual distribution of people to these resources is 27/73, indicating that there are fewer people at the more prolific resource than would be ideal, and in fact, the resources earned by the average person at the more prolific resource are greater than those earned by the average person at the sparser resource.

The group behavior studies presented above, their standard settings, their well-controlled conditions, represent the type of studies we want to conduct in 3D3C Worlds experiment. Similarly, the type of data collected in the above studies, e.g., timestamps, participant locations, and the gathering of resources, which allow for such analysis as shown in Fig. 5, is the kind of data we expect to obtain from successful well-controlled experiments in group behavior conducted in 3D3C Worlds.

## 2 Behavioral Experiments in 3D3C Worlds: Relevant Issues

Custom and vertical-market Virtual Reality platforms have been used in interdisciplinary research projects for over 20 years. The Research Directions in Virtual Environments report (Bishop & Fuchs, 1992, p. 156) stated as follows: "Though we still have far to go to achieve 'The Ultimate Display', we have sufficiently advanced towards the goal that is timely to consider real systems for useful applications."

In this Section, we present a review of social studies that have been conducted in 3D3C worlds, and compare their methodologies and implementations with the goals of studying human group behavior as a complex system by means of quantitative controlled experiments.

The parts comprising this section are shown in Fig. 6. We begin this section with a brief introduction to the problem of conducting social studies in 3D3C worlds.

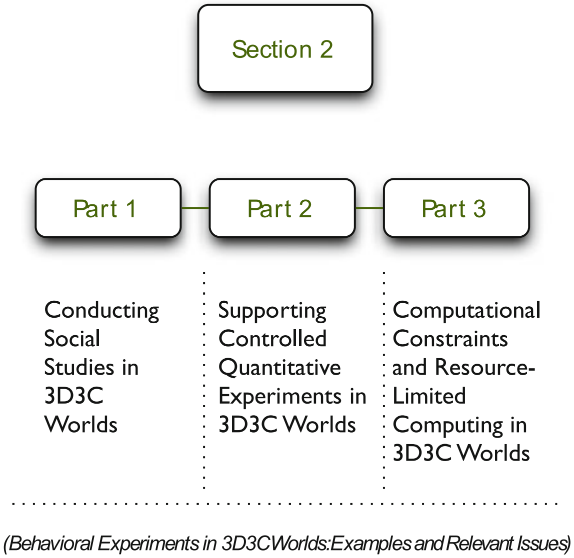



**Fig. 6** Organization of Sect. 2

**Table 1** Sutherland's ultimate display characteristics as presented in Sutherland (1965)

| | Characteristic |
|---|---|
| 1. | Display as a window into a virtual world |
| 2. | Improve image generation until the picture looks real |
| 3. | Computer maintaining world model in real time |
| 4. | User directly manipulates virtual objects |
| 5. | Manipulated objects move realistically |
| 6. | Immersion in virtual world via head-mounted display |
| 7. | Virtual world also sounds real, feels real |

A virtual world platform for group behavior experiments could have been designed and implemented in controlled laboratory settings by linking a number of high-end virtual reality devices installations: albeit extremely costly, the technical aspects would not have been insurmountable with technology such as the CAVE hardware (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992) and one of the shared-environment software frameworks implemented on that platform.

What has changed in the last 10 years is the availability of popular, well designed massively shared networked virtual worlds. In these, several requisites originally considered essential by "hard" Virtual Reality definitions (Brooks, 1998, 1999) remain unfulfilled, such as points (2.), partially (6.), and (7.) in Table 1, while the other aspects are well established in 3D3C Worlds and reachable to the point of becoming nearly "commodity."

A report summarizing an extensive feasibility study aimed at elevating 3D3C Worlds to a higher status than games (Yee, 2006, p. 310) motivated the expansion of social studies into networked virtual worlds: "[3D3C Worlds] provide a naturalistic setting where millions of users voluntarily immerse themselves in a graphical virtual environment and interact with each other through avatars (visual representations of users in a digital environment) on a daily basis." 3D3C Worlds have thus become an interesting platform for controlled behavioral experiments. The question about 3D3C Worlds including sufficient computing resources and interactive features for implementing such studies is examined in the next section in this chapter. It is important to understand where lay benefits in conducting controlled quantitative studies within 3D3C Worlds, and whether the methodological model used by the kind of experiments described in the previous section may be implemented in 3D3C Worlds.

## *2.1 Conducting Social Studies in 3D3C Worlds*

A review of scientific research conducted in virtual worlds presented in Bainbridge (2007) includes several reasons supporting the creation of virtual laboratory experiments in 3D3C Worlds, as shown in Table 2.

Since virtual worlds provide a 3D simulation of real world-like environments, and user avatars are designed to provide a realistic rendering of bodily features and movements, their actions and positioning can be studied to analyze their mutual

**Table 2** Advantages in conducting experiments in Virtual Worlds, as from Bainbridge (2007)

| | Relevant and potential advantages |
|---|---|
| 1. | The potential for recruitment of thousands of research subjects over an extended period |
| 2. | The capability of providing incentives to motivate participation, such as virtual currency or in-world perks for experiment participants |
| 3. | Software tools and virtual world modeling that allow the (re)creation of virtual laboratory settings |
| 4. | There is potential for new experimental designs, for conducting studies that were previously not possible |
| 5. | Classic experiments can be recreated within 3D3C Worlds to provide confidence in older results as well as to improve virtual world design skills |

placement, orientations and gestures. An observational study (Yee, Bailenson, Urbanek, Chang, & Merget, 2007, p. 115) aimed at analyzing whether "social behavior and norms in virtual worlds are comparable to those in the physical world," showed that established interpersonal distance and eye gaze social norms tend to transfer into virtual worlds, with results from male–male and female–female interaction analysis in Second Life—even though movements in virtual worlds are controlled by mouse and keyboard input devices. In "Coming of Age in Second Life: An Anthropologist Explores the Virtually Human" (Boellstorff, 2008) the virtual world of Second Life (SL) is showcased for its potential for residents engaging in extensive activities and interactions, from land exploration to forming relationships and building communities.

Studies comparing different levels of behavioral and form realism in person-to-person interactions (Bailenson, Yee, Merget, & Schroeder, 2006) examine the question of "how much avatar realism" in terms of form and behavior is critical to establish co-presence and self-disclosure in virtual world participants. In findings from these experiments, subjects disclosed more information (both verbally and nonverbally) to avatars that were low in realism, "emoting" more freely when their avatar did not express those emotions.

Other studies examine virtual worlds as a context for communication, focusing on the opportunities for conducting multiple conversations simultaneously (not unlike other online social venues) as well as possibly multiple virtual simulated places with their own separate visual and auditory contexts. This multiplicity of interaction contexts may induce users to keep a more careful tailoring of their presence and availability to communicate with others, for example by limiting or blocking voice channels altogether even when these become easily available (Wadley, Gibbs, & Ducheneaut, 2009). Of specific interest in this category are studies that can not be easily conducted by controlling aspects of the real world, or that would require the comparison of social and economic consequences of possibly mutually exclusive government policies, etc. A prominent example in this category are the studies described in Castronova (2001, 2005). These examine social and economic coordination in 3D3C Worlds, both by comparing results from different virtual worlds, as well as by implementing entire experimental virtual worlds of their own, independently designed and constructed: "There are major methodological advantages to addressing macro-scale social science questions using virtual world petri dishes." (Castronova, 2008, p. 15).

Further long-term examinations of 3D3C Worlds describe these platforms as being "unlike any other social science research technology" due both to the high numbers of participants and the opportunity of studying their populations with careful control of experimental conditions (Castronova, 2005, p. 1), suggesting that: "large games should be thought of as, in effect, social science research tools on the scale of the supercolliders used by physicists: expensive, but extremely fruitful."

A major incentive in using virtual worlds to explore social-scientific issues is the amount of time and resources spent in 3D3C Worlds by an ever-increasing portion of the non-specialized population, as well as the vastness of social interactions conducted within them. It thus becomes both meaningful and useful to compare results from studies researching different but comparable virtual worlds. World of Warcraft can be used to conduct extensive observational quantitative studies, because it already provides the capability of adding character behavior macros, or even longer scripts written in the Lua language—these range from auction system analysis tools, to census summaries, etc. A separate example of a software tool developed within the context of these studies is the Virtual Data Collection Interface, designed for use within Second Life to allow survey research using immersive Heads-Up Display (HUD)-based virtual instruments for "Virtual Assisted Self Interviewing" (Bell, Castronova, & Wagner, 2008).

## *2.2 Supporting Controlled Quantitative Experiments in 3D3C Worlds*

The study of collective behavior as a complex system, while in agreement with the motivations quoted above, requires research tools within 3D3C Worlds that are capable of supporting real-time controlled, and multi-condition experiments with limited subject pools per run, specifying the relevant environmental parameters and rules of interaction between participants on a run-by-run basis. The number of distinct factors needs to be carefully chosen and limited: real world situations, people creating new identities, etc., could easily become noise factors, hard to overcome or filter out. The Reference Studies method for group behavior studies in Second Life, as presented in this chapter, relies on its API's openly available and described capabilities to program experiments according to specific conditions, with interaction rules chosen in advance, rather than following a user space with potentially limitless variables.

The experimental model for target experiments in Second Life may be considered as a middle ground between social studies in the real world and the schematized, idealized group behavior experiments of a behavioral studies laboratory (the latter may also be referred as "clean-room approach"). The aim is to recreate in Second Life similarly controlled conditions to those employed in self-contained research games as presented in the above section. However, SL social rules, its users' habits, and ways of interacting are not be ignored. By integrating the architecture and design of group games within the established SL canon, experiment participants are allowed to continue their SL experience, bringing their own characters and in-world expectancies to the games, ultimately approaching experiment games within Second Life more seriously than they might in isolated laboratory settings. At the same time, to run controlled experiments without disruptions in the relatively unconstrained SL world environment, there will be necessary limits to those SL avatar behaviors that might otherwise permit participants' behavior within the group to compromise designed control conditions. Moreover, given Second Life's notorious griefer activities (Bakioğlu, 2007), it would be naively permissive not to block private script-running capabilities for subjects within the experimental environment boundaries.

### 2.2.1 Interactivity and 3D3C World Platform Capabilities

In any real-time group behavior study involving real-time visual output to subjects, tracking of their movements and decision-making inputs, one of the main required functionalities for designing an experimental environment is the capability to track and log all the relevant events, in order to record a timeline with known and specified precision. For time-stamped event logging in Second Life, the Linden Scripting Language (LSL) Virtual Machine (VM) provides access to the virtual world's time units, within the limits imposed by the Second Life Grid (SL Grid, i.e., the computing engine behind the Second Life 3D3C World) through its API functions.

Given the interactivity and time-logging requirements necessary to recreate in Second Life the kind of group behavior experiments described above, the platform capabilities listed in Table 3 need to be evaluated. The design of an interactive environment for these experiments is necessarily constrained by time response limits, memory/data limits, virtual geometry limits, etc.

**Table 3** Required SL Grid capabilities for designing controlled group experiments in Second Life

| | Required capability |
|---|---|
| 1. | Human Participant Tracking |
| 2. | Response Time to Avatar Input |
| 3. | (Quasi) Real-Time Computing Data Logging |
| 4. | Pseudo-physics (collisions, geometry interactions, avatars' degrees of freedoms) |

**Table 4** Obtaining unobtrusive observational data: methods and related issues as in Novak (2007)

| Precision | Methods |
|---|---|
| Higher precision | Positional (*XYZ* coordinates) with time stamp |
| ↑ | Presence in pre-defined spherical scanner regions |
| • | Object interaction (touch, buy, etc.) |
| • | Video (machinima)—video capture built into Second Life |
| • | Snapshots |
| ↓ | Chat logs |
| Lower precision | Avatar name, birthday |

| | Related issues |
|---|---|
| | XYZ coordinates require considerable effort to decode into meaningful units of analysis |
| | Sensors can be used to pre-code XYZ coordinate areas, but sensors can only scan activity in spherical regions |
| | Increasing the number of avatars tracked, and the frequency with which snapshots are taken, increases server load and compromises the performance of the sim |
| | How can one best deploy (position, scan frequency, number) both long and short range sensors to capture the needed data, but minimize lag and drain on resources? |
| | Capturing "touch" and purchase data requires buy-in of merchants, scripts will need to be added to their product displays |

## *2.3 Computational Constraints and Resource-Limited Computing in 3D3C Worlds*

As illustrated above, one of the main functional requirements for a software framework supporting human group behavior studies in a virtual world is the capability to gather real-time data about its residents. Such a software framework needs to be implemented within the computational constraints imposed by a 3D3C World's API, which can be characterized as resource-limited computing environment. This section examines the constraints imposed by the Second Life API that are relevant to a Reference Implementation, contrasting it to related methods employed by existing research tools in virtual worlds.

All interactivity and simulations in Second Life need to be scripted as LSL code embedded in object prims, including any program designed to obtain unobtrusive observational data. A summary of possible methods and issues related to obtaining this kind of information in Second Life is shown in Table 4, as from Novak (2007, pp. 39–43):

### 2.3.1 Human Participant Tracking

A record of experiment participants' positions is a common requirement for the kind of experiments described above. This type of data is indispensable for the correct functioning of the VM when simulating the virtual world, for avatar-object interactions, etc.; furthermore, all connected SL clients need real-time data for the correct graphical rendering of the "window into the virtual world", as outlined above.

While LSL API calls exist to provide information about agents present within a certain region, as in the sensor-level tracking method included in Table 4, these functions do not return exact locations for each detected avatar within a region of space. Other indirect methods exist for more precise user tracking: a commonly used technique is the implementation of avatar-worn code, as tested in initial code prototypes for our Group Behavior Virtual Platform presented in this chapter. Adaptive expertise studies (Weusijana, Svihla, Gawel, & Bransford, 2007) utilize this method to investigate residents' learning experiences in Second Life, for example, to track avatar motions through emergency situation dry-run simulations.

Literally embedding LSL code for avatars to "wear" is not permitted by SL design. It is however allowed for avatars to wear simple objects containing running LSL scripts. Direct positional data transmission from worn objects to other receiving LSL code would be too restricted by the SL architecture's imposed penalties for real time processing, so caching methods would have to be employed for complete experiment data logging, were this method otherwise acceptable.

### 2.3.2 Real-Time Visual Feedback for Subjects

The worn-script method just described has one crucial flaw in that it cannot provide any low-latency visual responses to avatars in a group behavior tracking situation, and visual feedback to participants is essential to recreate the experimental conditions described above.

Participants in the Forager and CPR Harvesting experiments, as presented in the previous section, search for resources—this goal needs to remain the same in the Second Life versions of these experiments. When a participant's avatar reaches a resource unit, their position must be detected, and two subsequent events need to take place: the participant needs to be notified of having found a resource (and subsequently rewarded for it), and the transaction has to be recorded. To support both these actions, the typical SL data-gathering solutions just described are not fast enough when implemented in LSL. To provide these functionalities, our Group Behavior Virtual Platform's architecture includes layered data processing, distributed caching, asynchronous communications and a designed graceful degradation. Together, these techniques successfully solve communication bandwidth restrictions and code penalties imposed by the platform.

### 2.3.3 (Quasi) Real-Time Computing

In CPR experiments such as the harvesting situation recreated in the Reference Implementation environment, as subsequently described, in-place processing is used to update resource availability, to provide a very simplified model of resource growth in nature. Participants have to manage a resource system consisting of a core resource part and resource fringe units. The type of computation involved in the model is not entirely dissimilar from mechanisms implementing arrays of Cellular Automata (CA), where each cell updates its status as a function of its neighboring cells' states. There exist interesting Cellular Automata implementations and other abstract machine simulations in Second Life, for example using synchronized agents to model individual cells (Crooks et al., 2009), but they do not provide usable speed for real-time support of 10–20 individuals interacting with the system simultaneously with the necessary scale for large surface data collection such as the Reference Implementation's 27 × 27 tile floor.

While the processing needs of such models (especially on the scale required by the supported experiments) may be trivial to satisfy on almost every available computing platform today, implementing this kind of functionality within Second Life is one of the most noticeably constrained tasks, due to limits imposed to LSL scripts in terms of operations per second, constrained data space, networking/communication penalties and unsupported data types. This is one case where originally planned functionalities had to be redesigned and partially altered to be achievable within the limits of the SL Grid, in order to maintain all the essential features of the experimental environment's resource growth mechanism in CPR experiments.

### 2.3.4 Data Logging

In addition to the functionalities described so far, an indispensable part of any quantitative behavioral experiment is the recording of all obtained data into a trail file, for data post-processing and analysis. Such "trail file" contains a chronological record of controlled activities, which may be subsequently used to re-play and examine the relevant aspects of each experiment run. Both to satisfy data security requirements for IRB approval, as well as to have complete control over the information obtained from experiment runs, all gathered data is transmitted to Common Gateway Interface (CGI) (i.e., web-based) servers that are external to the SL Grid, where the data can be safely stored and subsequently accessed without needing to rely on third-party systems. This task is again impacted by the limits imposed by the SL Grid to LSL scripts, specifically by the restricted data space constraining caching mechanisms, and by networking penalties associated with the various communication channels when transmitting data between SL Grid servers and any internet hosts outside its domain. In solving data logging-related issues, our Group Behavior Virtual Platform design has been—in a rare and unexpected instance—aided by Second Life's evolving platform capabilities, when the allowed networking limits were raised to a more usable level, during the timeframe of this work's first design and platform trial stages. Previously existing extreme penalties imposed by the SL Grid to out-of-grid communications were relaxed by orders of magnitude, easing potentially insurmountable limits in the framework's design.

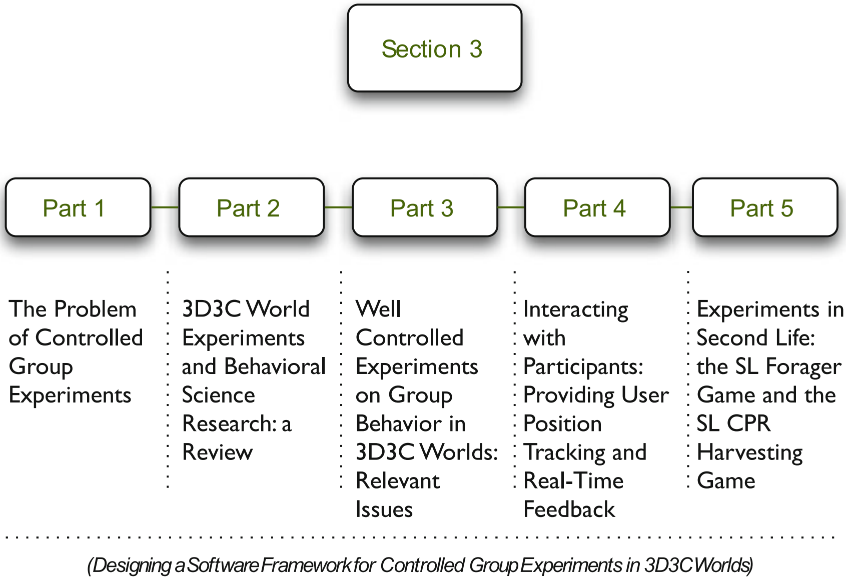



**Fig. 7** Organization of Sect. 3

## 3 Designing a Software Framework for Controlled Group Experiments in 3D3C Worlds

Functional requirements for the desired Group Behavior Virtual Platform are dictated by desired operational conditions for group behavior experiments. Non-functional requirements demand appropriate resource-limited computing methods within the highly multithreaded platform provided by the SL Grid.

The parts comprising this section are shown in Fig. 7. This section reviews the design aspects of various existing social behavioral research tools in virtual worlds, with particular focus on the goal of satisfying both functional and non-functional requirements that are relevant to studying human group behavior as a complex system, and conducting well controlled quantitative experiments in virtual worlds. We present a review of social studies that have been conducted in 3D3C Worlds, and compare their methodologies and implementations with the goals of studying human group behavior as a complex system by means of quantitative controlled experiments. Finally, we propose a design for an experimental platform in 3D3C worlds: our Group Behavior Virtual Platform, which has been successfully deployed to run series of experiments in Second Life.

## 3.1 The Problem of Controlled Group Experiments

The goal of the experiments supported by the described Reference Implementation is to research how groups of human subjects act when each individual faces the task of gathering valuable resources for personal benefit, where the outcome depends on the entire collective's behavior. The real-life situations that this system is designed to simulate are part of studying how human subjects allocate themselves to available resources in specified environments (group foraging), and to analyze how collective groups manage Common Pool Resources (CPR), i.e., group harvesting. All experiments are therefore set in environments where desirable virtual resources are provided for participants to collect. The blueprint for the foraging experiments is derived from an experimental technique developed for studying human foraging behavior utilizing a 2D computer game-like platform, the Forager Applet presented in Sect. 1, Fig. 3.

## 3.2 3D3C World Experiments and Behavioral Science Research: A Review

### 3.2.1 Manipulation Rules and Experimental Constraints in Group Behavior Studies

Computational models of agents are oftentimes used in social simulations, where agent-based modeling describes large-scale system behaviors by modeling the individuals that compose the system. In designing controlled group behavior experiments, the Reference Studies presented in this chapter aim for relatively pure, idealized experiments that fit well with similarly pure and simple agent-based models. Most studies where data are collected about online group behavior e.g., in web-based communities, are too complicated to be easily compared to agent-based models without adding many situation-specific details to the models. By creating a Reference Implementation for a social behavioral research platform, a simple self-contained world can be designed so as to be in agreement with agent-based model assumptions. By imposing fairly simple rules and well-defined constraints, there is less to worry about participants manipulating their identities, about cheaters and other intentional or unintentional disruptive behaviors in participants.

### 3.2.2 Repeatable Controlled Experiments

A review presenting the scientific research capabilities of virtual worlds (Bainbridge, 2007, p. 473) compares the potential for human behavior studies in Second Life (SL) and World of Warcraft (WoW): "In terms of scientific research methodologies, one can do interviews and ethnographic research in both environments, but other methods would work better in one than the other. SL is especially well designed to mount formal experiments in social psychology or cognitive science, because the researcher can construct a facility comparable to a real-world laboratory and recruit research subjects. WoW may be better for nonintrusive statistical methodologies examining social networks and economic systems, because it naturally generates a vast trove of diverse but standardized data about social and economic interactions. Both allow users to create new software modules to extract data."

A virtual experiment room in Second Life has to allow the experimenter to set different conditions and to schedule well-defined experiment runs where selected variables are manipulated and controlled. In general, experiment reliability is achieved by supporting repeatability of experiments having exactly the same conditions and a sufficient number of groups of participants. The Reference Implementation therefore also directly provides for arbitrarily repeatable and fully programmed controlled experiments, in contrast to naturalistic investigations of 3D3C Worlds such as World of Warcraft, studies of social norms in Second Life (Yee et al., 2007), studies of web communities, etc.

A visual comparison of the Second Life virtual room in the Reference Implementation (configured for the Forager experiments) and the Forager Applet online game is shown in Fig. 8.

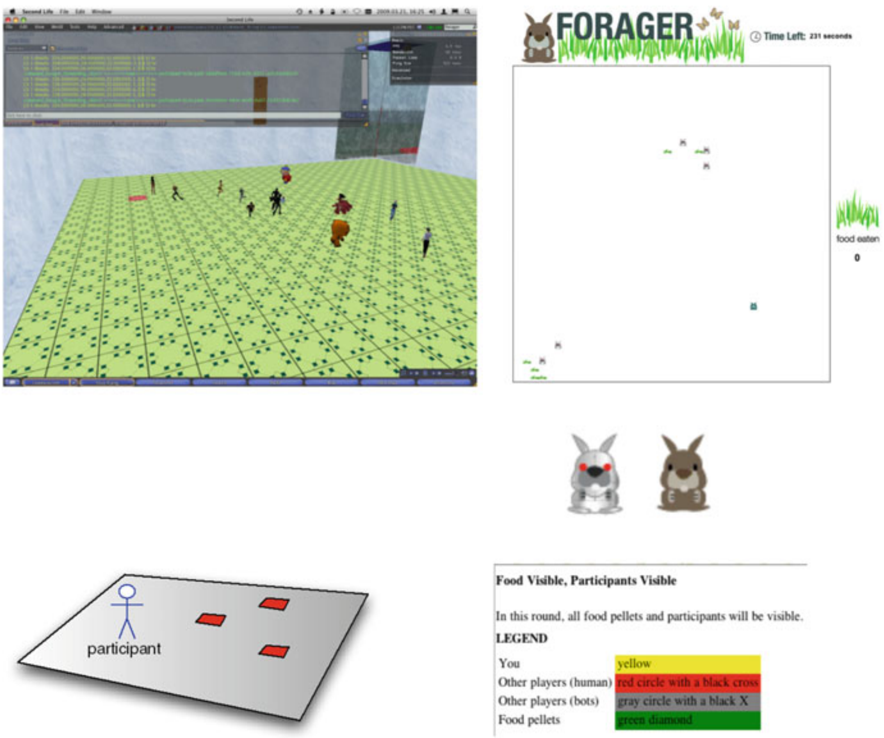



**Fig. 8** The Second Life Forager experiment compared to the Forager Applet online game environment

### 3.2.3 Automated Survey Tools

Among the multitude of programmable tools for conducting survey studies entirely within Second Life, a significant example is the Virtual Data Collection Interface (VDCI) (Bell et al., 2008). Their work has produced a tool in the form of an in-world immersive Heads-Up Display (HUD)-based virtual instrument for "Virtual Assisted Self Interviewing" (VASI), which has then been made available to the SL research community, as advertised on the Second Life Researcher's List (SLRL) (Bell & Robbins, 2008). The VASI methodology is quantitative in its data gathering capabilities, and these studies aim at researching optimal sampling frames and sampling procedures within 3D3C Worlds like Second Life. While not targeting controlled experimental environments, the VDCI tool's development shows how the computing infrastructure available to Second Life's end-users and LSL developers offers valuable resources to allow the automation of survey research in 3D3C Worlds.

### 3.2.4 Adaptive Expertise Studies

Another line of behavior-related research in Second Life, albeit with quite distinct goals from the experiments supported by the described Group Behavior Virtual Platform, includes some computational aspects related to the functional requirements that became one of the main resource-limited computing problems that had to be solved for a fully functional Reference Implementation. The goal of Weusijana et al. (2007, p. 34) is described thus: "Adaptive expertise, briefly, is the idea that expertise is dissociable into innovative and efficient dimensions, and that not all experts or learning experiences equally incorporate both. [...] Second Life (SL) makes it possible for students to experience events first-hand rather than simply learn about them secondarily. [...] This chapter's specific study addresses a more important goal [...], to help people learn about adaptive expertise by enabling them to experience differences between 'efficiency' and 'innovation' modes [...]" This Adaptive Expertise study in Second Life aims at investigating SL residents' learning experiences, for example in emergency dry-run simulations. Analyzing subjects' responses requires avatar motions to be tracked through such situations. This solution requires participating avatars to wear SL objects containing running LSL scripts, which can in turn transmit positional data tracking the worn object's location to other receiving LSL code. For a study that does not involve groups of interacting participants, nor does it require complex real-time visual feedback based on the processing of multiple avatar inputs and cellular automata-like rules, the avatar tracking method implemented by avatar-worn code is sufficient for the considered situations.

### 3.2.5 Longitudinal Behavioral Data Collection

Another approach, similar to the one just described, has been presented in Yee and Bailenson (2008, p. 594) with the goal of providing a foundational framework within Second Life for measuring interesting behavioral variables, both for individuals as well as at the group level, to be transmitted off-world for further analysis. Their solution also utilizes avatar-worn objects containing LSL scripts for positional tracking: “The solution we describe allows researchers to capture avatar-related data from Second Life (SL) at a resolution of one minute or less over a period of weeks.”

Equivalent methods for subject position tracking have been tested in initial experimental trials to evaluate their performance within SL for the purposes of the Reference Studies described in this chapter, but were found inadequate in supporting low-latency tracking of multiple avatars in group situations with real-time visual feedback based on their locations, due to bandwidth limitations within the SL platform.

## *3.3 Well Controlled Experiments on Group Behavior in 3D3C Worlds: Relevant Issues*

Two representative examples of well controlled experiments on group behavior, presented in the above section “Group Behavior Studies: Background and Overview”, are the Group Foraging applet and the CPR Harvesting experiment. An effective implementation capable of supporting equivalent experiments in 3D3C Worlds necessarily differs from the quantitative studies tools and methodological approaches just described (e.g., Automated Survey Tools, Adaptive Expertise Studies, Longitudinal Behavioral Data Collection). A well controlled study on group behavior aims at conducting controlled experiments with groups typically comprising 10–30 human subjects, where specific parameters and rules of interaction between participants and the environment can be set on a run-by-run basis. The approach presented here is a compromise between two extremes: experiments or analyses of group behavior in the real world, and idealized experiments of a clean-room approach. This approach led to the design and implementation of two set of experiments that are part of the Reference Studies in Second Life considered throughout this chapter: the SL Forager game and the SL CPR Harvesting game.

### 3.3.1 Considerations About Second Life’s Social Environment

While aiming at the idealized conditions of self-contained research games, the described Reference Implementation is nevertheless bound by Second Life rules and its users’ habits, ways of interacting and expectancies.

This also means that the design of our Group Behavior Virtual Platform has to adapt the original Group Behavior Studies experiments to SL users, e.g., allowing for specific avatar appearances, as well as control of those aspects of SL avatar behavior that would allow for undesired degrees of freedom in participants' actions within the group, such as movement capabilities within the world—typical instances would be avatars flying, or running their own scripts, within the boundaries of the experiment room space. These capabilities are both blocked at the level of virtual ground property permissions, so that for example participants who may enter the briefing/debriefing area while their avatar is in flying mode, will not be able to resume flying once their avatar lands on the briefing area, and especially not after having been teleported into the Reference Implementation experiment room.

Supporting the use of Second Life's virtual world for human social interaction research, an extensive study presented in Yee et al. (2007, p. 119) aims at comparing social behavior and norms in virtual worlds to those in the real world: "Overall, our findings support our hypothesis that our social interactions in online virtual worlds, such as Second Life, are governed by the same social norms as social interactions in the physical world. This finding has significant implications for using virtual worlds to study human social interaction. If people behave according to the same social rules in both physical and virtual worlds even though the mode of movement and navigation is entirely different (i.e., using keyboard and mouse as opposed to bodies and legs), then this means it is possible to study social interaction in virtual worlds and generalize them to social interaction in the real world."

As a further corollary of these studies' conclusion, and supporting the relevance of controlled group behavior experiments within 3D3C Worlds, one can infer that SL residents may treat games taking place entirely within Second Life (such as the forager and harvesting scenarios implemented within the described Group Behavior Virtual Platform) more seriously, as some kind of real life extension. By participating in these games, 3D3C World residents simply continue their SL experience, bringing their own characters and in-world existence to the games.

### 3.3.2 Tracking Individual Actions and Supporting Experimental Control Conditions

Participants in the SL Forager and SL CPR Harvesting experiments/games have the implicit task of gathering resources, and are rewarded with Linden Dollars for collecting them. This process has several complicated data transmission and communication constraints. For example, when a participant's avatar steps on a floor tile in the experimental virtual room, their position is detected by the tile's activity monitor script handling collision detections. If the tile contains one of the resources being sought, two things need to happen: the participant needs to be notified, and the transaction has to be recorded for monetary reward. In the SL CPR Harvesting experiment, further processing is required for computing the next growth of resources.

All these actions must happen within a reasonable time, in order to maintain responsiveness for all participants in the game—it is essential, for the design conditions to be valid, that every subject experiences seamless experimental conditions. This translates to a non-functional requirement for our Group Behavior Virtual Platform: the necessity of near-real-time visual feedback to all user interactions with the active objects in the virtual world, with an allowed time for all processing between user input and the feedback response from the virtual interface to be contained within the order of magnitude of 1 s.

By comparison, one of the most extensive studies of group behavior in Second Life (as illustrated above) had quite different data collection and processing time constraints. Their study, presented in Yee et al. (2007, p. 117), also made use of LSL scripts to collect positional information from present avatars. However, that method employed a massive force approach, with research assistants working for an extended period of time, and manually triggering scripts where groups of SL avatars were interacting: "A triggered script was used to collect information from avatars in the world. When triggered by a designated key press, the script would collect the name, Cartesian coordinates (x, y), and yaw of the 16 avatars closest to the user within a 200 virtual meter radius. The script would also track whether the avatars were talking at that given moment. The script would then store the information as a text file. Six research assistants, paid at an hourly rate for 10 h a week, collected data within Second Life over a period of 7 weeks. There were 688 zones (discrete locations) in Second Life, and undergraduates were each assigned to 115 zones. These research assistants were instructed to systematically explore the zones and trigger the script near locations where a group of at least two people were interacting."

Specifically, in that study there was no need for immediate feedback to subjects. A closely related work provides a solution for behavioral research in Second Life with automated scripts allowing the tracking of subject data at a resolution of "one minute or less over a period of weeks" (Yee & Bailenson, 2008, p. 594).

Given that such approaches could not satisfy the application goal for an experimental software framework with near-real-time user feedback and well-defined processing time constraints, different options needed to be explored for tracking each individual avatar's data in groups of subjects interacting within a dynamic virtual world.

## *3.4 Interacting with Participants: Providing User Position Tracking and Real-Time Feedback*

### 3.4.1 Avatar Locations

Keeping an accurate record of every participant's position is a common requirement for all of the experiments supported by our Group Behavior Virtual Platform. This would initially appear to be trivially satisfiable: the Reference Implementation has been located within a Second Life region maintained by Indiana University research support personnel, therefore complete administrative access is available over simulator status. Also, all participants access the experiment room with their Second Life avatars, and the virtual world server-side engine necessarily keeps track of each avatar's position with maximum possible accuracy, so that all connected clients may receive real-time data about the region in which they are connected, to make correct rendering possible. This continuous data stream contains updates on every object primitive and avatar's locations within a region.

### 3.4.2 Restrictions Imposed by the LSL Function Library

One fundamental limitation faced by every program running on the Second Life grid is defined by the set of functions available in the LSL API. These function calls are the only way provided to LSL programmers to access data from the Second Life grid. For the purpose of programmable access, each Second Life participant's avatar is referred to as an agent, and it has both a uniquely defined name (Second Life user's first and last names) as well as a unique key—a string of alphanumerical characters that is assigned to a user when their account is initially created.

Once an avatar's first and last name are known, it is trivial to obtain their unique key string by querying the Second Life server-side database using LSL API functions. The knowledge of this key's value is necessary to programs detecting avatar actions, because it is the only way API function calls use to identify detected agents.

### 3.4.3 Tracking with Sensor Sweeps

The accepted way to track any user in a 3D3C World is to have available a function call returning a list of the avatars and their locations present in the virtual space. This is especially true for applications in which the rendering of the environment depends on the virtual location of the end user.

There are available methods in the LSL library that provide an apparently usable way to inquire about agents present within a certain region: such functionality is considered necessary, for example, in order for a virtual land owner to be able to measure usage and average occupancy within a region. Unfortunately, these functions do not return a precise location for each detected avatar within a region of space. The most that can be achieved by using these methods is a rough approximation of positional tracking: sensor code built using them can provide a maximum accuracy of detection within a 10 m radius, where the available precision goes down to 1 mm. For example, each end user has a constantly updated display of their virtual location within the occupied region, expressed in (x, y, z) coordinates with the precision of 1 mm. However, direct tracking of agent positions is completely missing from the library functions available to LSL scripts, and the 10 m radius is the best that can be achieved in terms of direct queries.

### 3.4.4 Tracking with Avatar-Worn Scripts

Since unmediated direct determination of avatar positions is impossible in Second Life, the necessary functionality needs to be achieved in some other way. An attempt at a working method was devised through the use of avatar-worn objects containing scripts. This method provides tracking data by avoiding two additional limits in the Second Life design, which intentionally prevents any avatar from containing LSL code, even though avatars and independent objects are both built using Second Life primitives. Secondly, even code-containing primitives cannot be directly queried for their position. This widely used method works by having avatars wear simple objects (such as a hat), which in turn contain LSL scripts internally tracking their own position. This is possible by LSL API queries. Because an object worn by an avatar becomes at that point the avatar's property, any external code that is part of the Reference Implementation game room can only attempt to communicate with its LSL code through standard, textual-chat channels. This would seemingly provide a usable method of tracking avatar positions in real time:

- Avatar-worn code. Each participant wearing a provided tracking hat would have their position tracked by the script in the hat. Although that script could continuously broadcast its position, that would create chat channel bandwidth saturation if the experiment were to run with the expected number of participants (10–20). Instead, each worn code can simply keep track of its position in a time-stamped local variable, which can be then queried when necessary by the experiment tracking object. With this mechanism, the avatar-kept code can cache thousands of time-stamped positions. Test run actions typically required them to store up to a couple dozen events before being queried, and therefore this was not a source of resource constraints.
- Experiment controller object. As part of the tracking context, the main task of the experiment tracking object is to be the listener that periodically queries avatar-worn code for their positions, and subsequently receives all their updates.
- Chat-based communication channels. The exchange of query/response pairs between avatar-worn code and the controller object has to happen using the only available communication mechanism for unlinked objects, namely the chat channels. The limitations of chat channels include low bandwidth and the absence of guarantees that flow latency would not cause unacceptable delays. These problems ultimately caused us to discard this approach entirely.

An avatar-worn object containing LSL tracking code is depicted in Fig. 9. In the testing environment illustrated there, sample feedback was provided by a detached object replicating the avatar's movements on the floor in a wall-mounted display fashion. Even with a single avatar being tracked with this mechanism, the delay in the replicating object's movements compared to the avatar's was on the order of a couple of seconds on average. Given that each LSL script employing a chat channel listener callback function introduces a delay in the overall responsiveness (lag) of


**Fig. 9** Experiment participant tracking: avatar-worn scripts

the Second Life simulation, the negative effects of this methods when applied to several SL users would be cumulative.

To sum up, the avatar-worn code could adequately record and store the time-stamped locations, and that data could be transmitted to the experiment controller object correctly via the chat channel, preserving all necessary information for subsequent analysis. However, the requirements of providing timely feedback to participants could not be met by this method. For example, participants would experience several seconds of delay in being notified of the successful collection of resources.

The data-collection objectives of the supported experiments could easily have been met by the above method, since time-stamped location data would have been adequately collected. The primary issue that prompted us to abandon this approach, and look for another one, was exclusively in this method being unable to provide all participants with feedback within a tolerable time delay. Since it is necessary to enable subjects to notice the effects of their actions in the game in real time, another method entirely had to be developed to support the interactive virtual experience of the experiment's dynamics. The first two tested approaches to avatar tracking—area sensor sweeps and avatar-worn scripts—are illustrated in Fig. 10, together with properties, constraints, and platform-imposed penalties for each of these two methods.

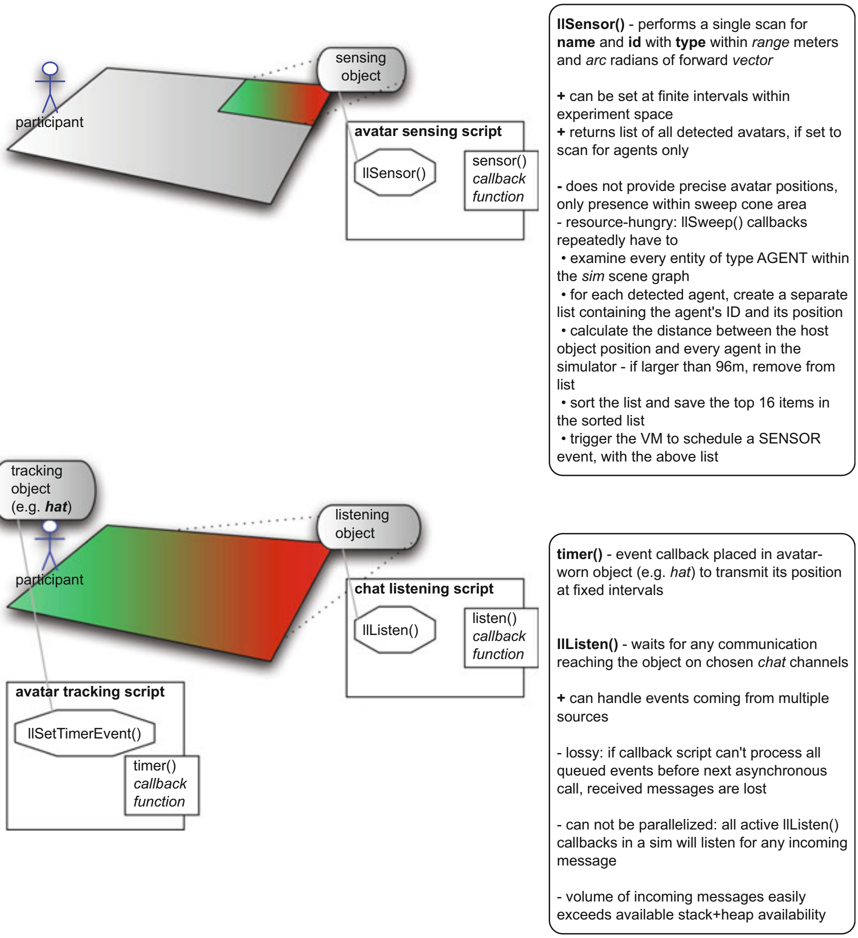



**Fig. 10** Avatar tracking—first two approaches: area sensor sweeps and avatar-worn scripts

### 3.4.5 Collision-Detection Scripts

In order to work around constraints imposed on us by chat channels, a new approach had to be developed to identify avatar locations, track and log their movements, and notify them of resource collections. Initially, individual LSL scripts in each one of the $27 \times 27$ floor tiles reported back two main detected events (money generation and avatar collision detection) through chat channel communications to a centralized controller script running in a separate object. This communication method is not unlike the tracking hat transmitting positional data to an external object, as presented in the previous Section. One main difference in using collision detection scripts is the employed event-based mechanism, which only executes when avatars actually interact with the environment, thus avoiding idle-time processing.

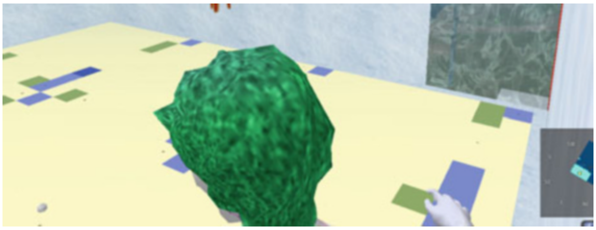


**Fig. 11** LSL scripts using chat-channel communications

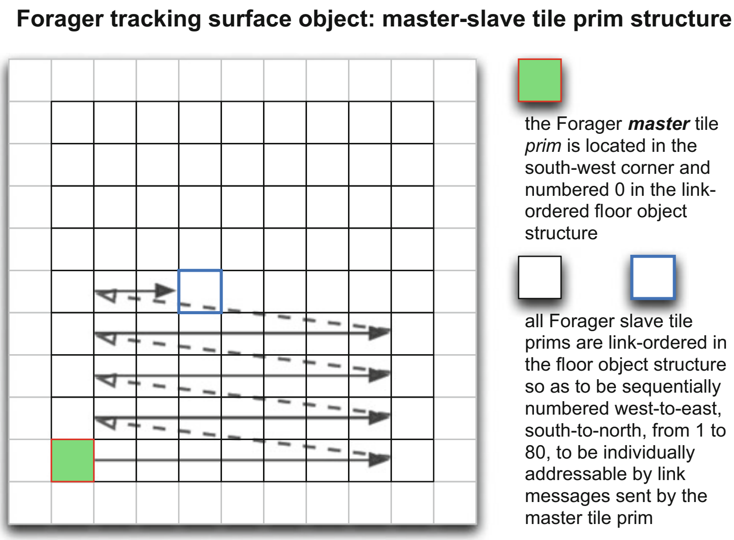



**Fig. 12** Avatar tracking surface 9 × 9 subset (final version)

Figure 11 shows an early test of this message passing structure. Here, collisions were simulated with automated randomly generated events at the rate expected during a fully populated game. This method still proved to be unfeasible, due to chat channel bandwidth limitations: having all 27 × 27 floor tile scripts reporting to a single controller object saturated the chat channels. To overcome the bandwidth limitations, a multi-level communication strategy was developed for the experimental room's interactive floor to track avatar locations in real time, while still allowing enough processing time to provide real-time user feedback. Figure 12 illustrates the final structure of each subset of the experiment room's tracking surface. It consists of 9 × 9 linked prims: one master tile containing scripts for receiving chat channel command messages and collecting resource-tracking events, and all tiles containing resource and avatar tracking scripts.

The in-world modeling process of the avatar tracking surface is shown in Fig. 13 with individually highlighted linked prims.

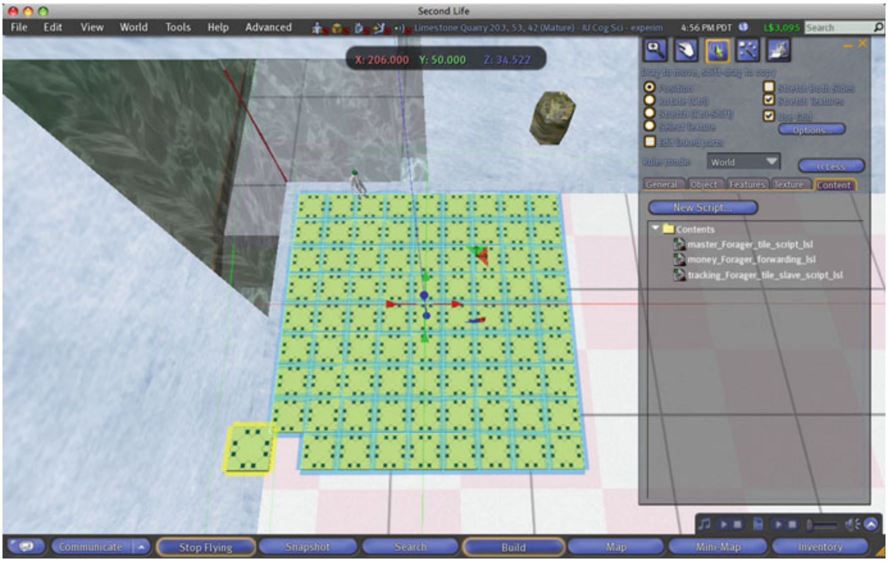



**Fig. 13** Modeling the avatar tracking surface: the master tile is shown extruded from the $9 \times 9$ structure. The LSL scripts contained in the master prim are listed in the editing window on the *right side*

### 3.4.6 Reward Process

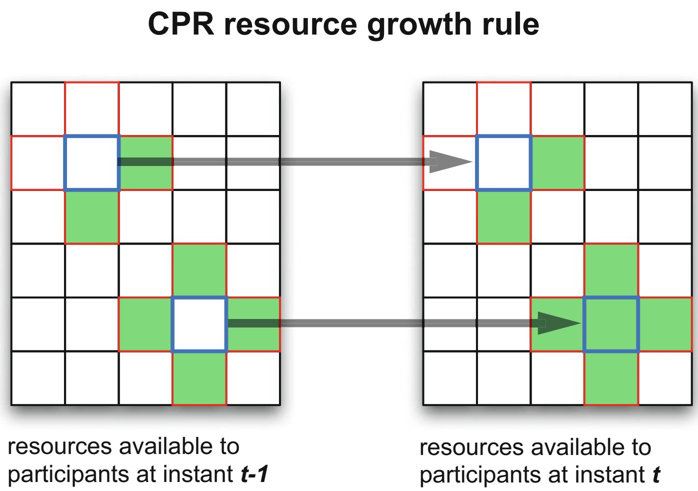
Participants could be rewarded immediately every time they discover and enter a tile containing a resource, and there would be two implications: firstly, being immediately rewarded would not encourage participants to continue playing until the end of the experiment. Secondly, virtual monetary transactions would have to happen continuously during the experiment. Neither of these is desirable for the purposes of the Reference Studies. Therefore, at resource discovery time, participants only receive a notice of having collected a resource, and instead of starting a monetary transaction process, this specific resource-collection event gets recorded by a bookkeeping script.

The messaging mechanism requires a complex strategy to accommodate the computational and communication constraints. In both experiments, each active floor tile contains a script that passes a message (relayed by the master prim in each $9 \times 9$ subset) to a command center listener script, which is ready to act on this information. The command center listener script keeps track of monetary transactions belonging to each participant. This communication still relies on chat-channel messages: instantiating a listening event callback function is in itself considered computationally demanding for the LSL API, but having only one listener for this particular functionality is acceptable. One listener can process a sufficient number of messages without being overloaded by the incoming data arriving from nine master prims, one for each $9 \times 9$ subset. The command center script keeps track of all these transactions for each participant in a local list, which is then emptied at the end of each experiment run, when all subjects are rewarded with the actual Linden Dollars corresponding to their total collected resources.

During the experiment there would therefore be no explicit message given to participants each time they discover a resource. In the case of visible resources, the tile containing Linden Dollars turns from red back to its neutral color, but in the invisible resources case, there is no such visible change. However, in both cases a brief message is sent out by the individual tile to the chat channel, showing that a resource has been acquired by the named participant at a specific location. It is not an immediately helpful aid for finding transaction locations, but it gives participants feedback about the progress of the foraging.

By disallowing immediate monetary transactions, the game's user interface became more fluid and less cluttered for participants—specifically by avoiding visual interruptions. By default, every time one's avatar is given Linden Dollars, the SL Viewer signals the transaction with a bright dialog box that requires explicit action to acknowledge and dismiss the box. In the Reference Implementation, this happens only once for each participant, at the end of an experiment run.

Another important advantage in using a deferred payment mechanism is its implicit ability to counteract money-detection radar tools, known to many (but not all) Second Life participants. Removing money-giving functionality entirely




$$p_c(t) = p\frac{n_c(t \quad 1)}{N}$$

$n_c$ = number of active adjacent cells

$p$ = growth parameter

$N$ = 4 - connected (or 8 - connected) neighborhood

**Fig. 14** CPR experiment: resource growth step from all parts of the virtual world and activity monitors prevents us from being gamed by participants using scavenging tools; the overall integrity of the experiment is thus increased by the employed reward mechanism.

### 3.4.7 Continuously Monitoring Monetary Acquisitions in the CPR Experiment

The deferred payment mechanism just described is necessarily implemented in all the presented Reference Studies experiments. In addition, in the SL CPR Harvesting experiments, monetary transactions are also part of the resource growth mechanism that constitutes the main characteristic of the harvesting scenario. Therefore, these transactions need to be constantly monitored for the correct computation of each subsequent cycle. Any empty floor tile in the SL CPR Harvesting game has a probability of generating a new resource, depending on the presence and proximity of neighboring resources, as shown in Fig. 14. This process happens in cycles, and therefore a separate monitoring mechanism is required.

To conclude, Table 5 summarizes the required properties for a platform capable of supporting well-controlled experiments on group behavior in 3D3C Worlds.

**Table 5** Requirements for "lab-like", well-controlled group behavior experiments in 3D3C Worlds

| | Characteristic |
|---|---|
| 1. | *Topological Consistency*. Primitives and building blocks used for every construction within the 3D3C World, their size, orientation and location need to be consistently represented in a Cartesian coordinate system that extends throughout the virtual world |
| 2. | *Immediate Accessibility*. Every aspect of avatar interaction and scripting capabilities need to be immediately available to all participants. There should be no levels to be reached, nor abilities that a participant's avatar needs to achieve in order to start moving. Unlike some 3D3C Worlds where gaming characteristics dominate (such as World of Warcraft), this characteristic effectively requires the leveling of the entry field for all users |
| 3. | *Tracking Avatar and Object Locations*. Each avatar's position within the virtual world needs to be fully determined at any given time, i.e., the current simulator region, the current (x, y, z) coordinates within that region. Likewise, each primitive and each object needs to be uniquely determined in their location. In the Reference Implementation, this is achieved with distributed micro-processes and problem-dependent data optimization |
| 4. | *Permanent Data Logging*. A continuous and detailed data trail has to be provided, either within the 3D3C World, or by logging facilities hosted on remote off-world servers. Our Group Behavior Virtual Platform employs layered communications to this effect, with on-demand buffering and data logging |
| 5. | *Data Access and Searchability*. For data with inherent spatial properties, it is beneficial to pre-organize data in a structure reflecting such properties, to allow localized interactive features and front-end localized storage |
| 6. | *Interactivity*. A decision policy needs to be established about which computing instances to keep active within a Reference Implementation, in order to maintain the required interactivity for expected groups of simultaneous users. Anomalous load increases need to be handled by graceful degradation |

The above table corresponds to the main features provided by the "Reference Implementation" of our Group Behavior Virtual Platform as deployed in Second Life.

### 3.5 Experiments in Second Life: The SL Forager Game and the SL CPR Harvesting Game

The structure allowing interactive experiment control from authorized Second Life avatars (i.e., the experimenters) is shown in Fig. 15. The presented Group Behavior Virtual Platform satisfies the computational requirements necessary for running controlled group experiments entirely within Second Life, employing in-world native LSL scripting capabilities, and transferring all data collection and storage tasks off-world. The framework provides control over experimental settings such as avatar room access, parcel access, preventing participants running scripts, and flying.

The methods, design and implementation presented in this chapter, were successfully deployed in two sets of experiments in Second Life: the SL Forager game

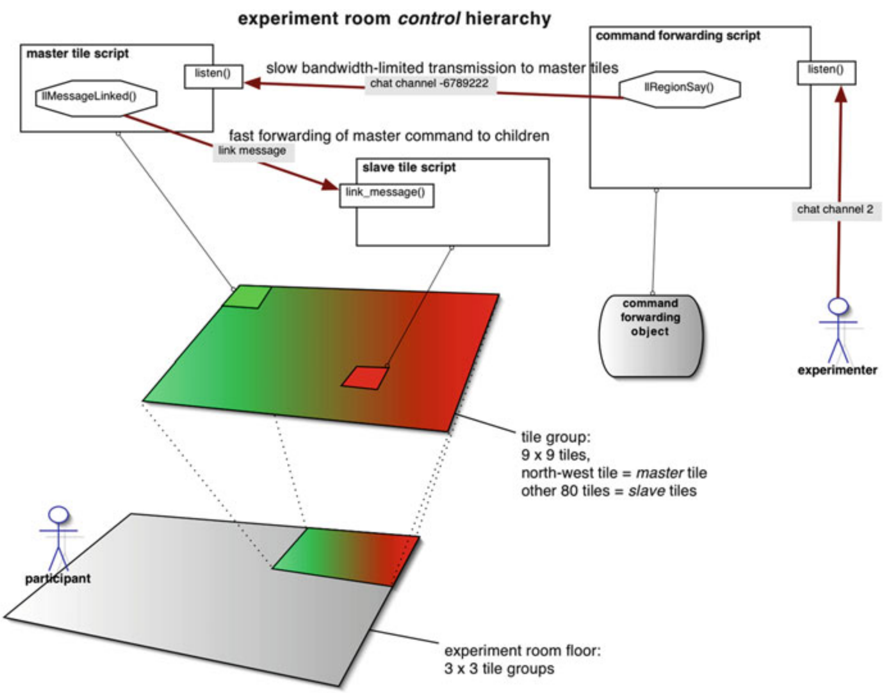



**Fig. 15** Second Life Forager experiment control structure

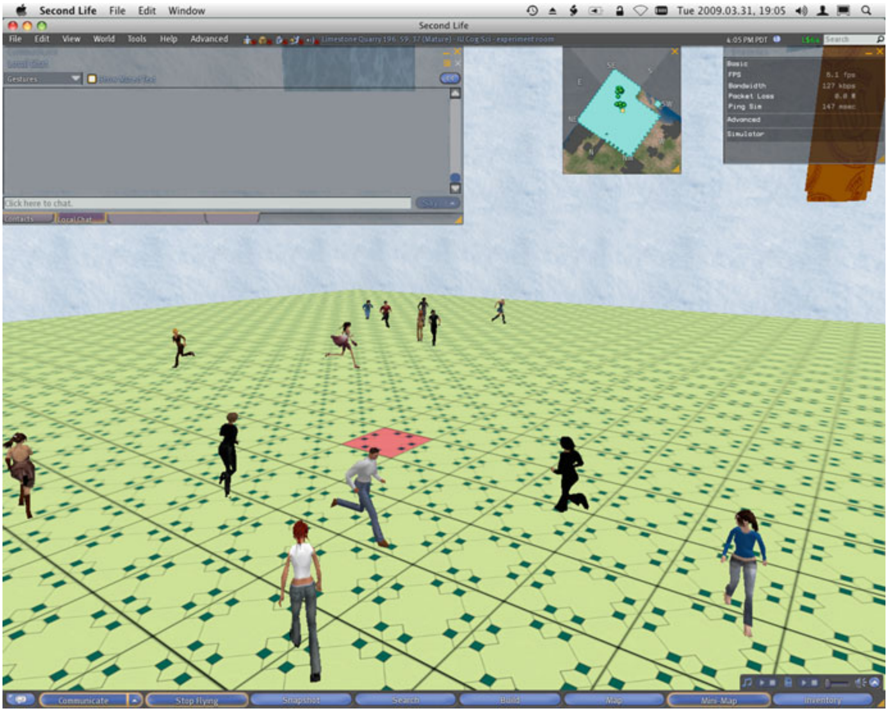



**Fig. 16** *SL Forager* experiment snapshot: a typical view of a game run. The participants forage for resources, represented by *red-colored tiles* on the experiment room floor

and the SL CPR Harvesting game, as described in Hmeljak (2010). Runs from these two experiments are shown in Figs. 16 and 17.

## 4 Conclusions

This chapter presented examples of social behavioral research in virtual worlds, their methodologies and goals. For this review, the chapter considered the requirements for a Group Behavior Virtual Platform providing the experimental environment for well-controlled group behavior studies in SL, comparing its functionalities to established social behavioral research tools in Second Life. By leveraging the existing community of a 3D3C World, these studies can scientifically analyze the patterns that motivated people make when they are given tasks that require group adaptation, coordination, and cooperation. The chapter also provided a description of the employed methods of subject tracking and experimental condition controls in the virtual world, highlighting relevant aspects of the proposed design dictated by platform constraints.

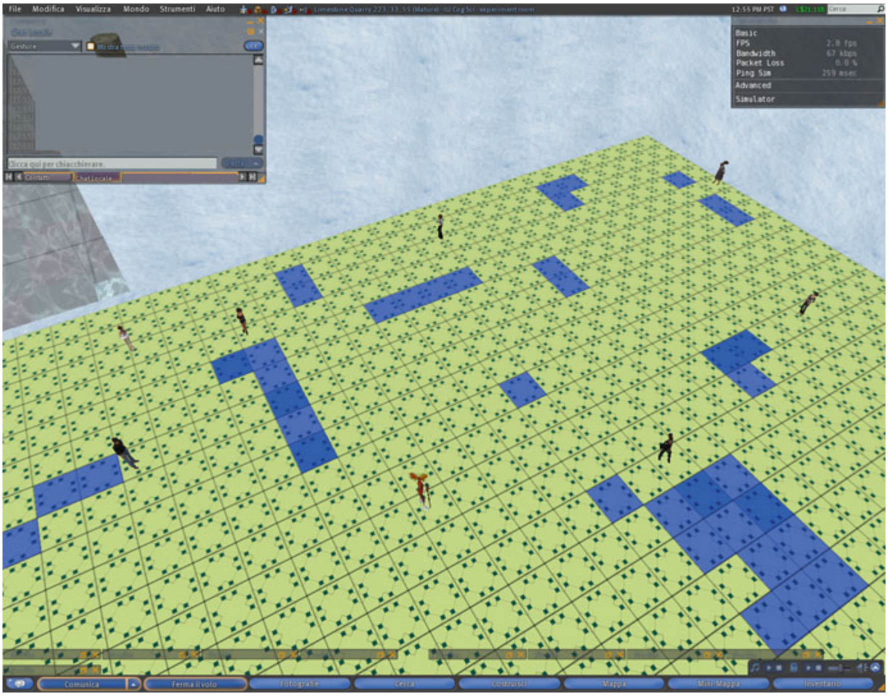



**Fig. 17** *SL CPR Harvesting* experiment snapshot: during the harvesting game runs, some participants would choose to gather resources right away, while others chose to wait for more resources to grow

There are also possible settings and controls that could not be fully controlled within Second Life at the time of our Reference Implementation. While not impacting the kind of experimental applications supported by our Group Behavior Virtual Platform, it is appropriate to add here a list of some of these experimental aspects that fall outside the scope of the work presented in this chapter:

- The visual perception of SL objects cannot be precisely controlled: the rendering options of each individual participant's SL viewer client software can be set to widely different settings. The only partial workaround for work requiring at least partial visual uniformity among participants is to choose neutral colors for all prims, to avoid bump mapping or additional shininess properties that may require post-processing, and to forego any complex polygonal structures that may get automatically reduced by individual SL viewer's optimization settings.
- The point of view of participants within the experiment room cannot be imposed by in-world scripts. Each SL resident can freely move their camera point of view away from the default "eye" position.
- SL instant messaging and chat-channel communications between participants cannot be prevented in any way. SL chat between participants can at most be

monitored—at acceptable additional processing expense—but the current experimental applications enabled by the described Group Behavior Virtual Platform do not include such requirements.

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## References

Bailenson, J. N., Yee, N., Merget, D., & Schroeder, R. (2006). The effect of behavioral realism and form realism of real-time avatar faces on verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction. *Presence: Teleoperators and Virtual Environments, 15*(4), 359–372.

Bainbridge, W. S. (2007). The scientific research potential of virtual worlds. *Science, 317*(5837), 472–476.

Bakioğlu, B. S. (2007). Collaborative story-telling: Performing the narrative of the griefer. In *Proceedings of the Second Life Education Workshop 2007* (pp. 41–46). Chicago: Second Life Community Convention.

Bell, M. W., Castronova, E., & Wagner, G. G. (2008). Virtual Assisted Self Interviewing (VASI): An expansion of survey data collection methods to the virtual worlds by means of Virtual Data Collection Interface (VDCI). *Data Documentation* 37, DIW Berlin, German Institute for Economic Research, 2008. Retrieved from http://ideas.repec.org/p/diw/diwddc/dd37.html

Bell, M. W., & Robbins, S. (2008). *Second Life researcher's list, 2008*. Retrieved from http://list.academ-x.com/listinfo.cgi/slrl-academ-x.com

Bishop, G., & Fuchs, H. (1992). Research directions in virtual environments. *Computer Graphics, 26*(3), 153–177.

Boellstorff, T. (2008). *Coming of age in Second Life: An anthropologist explores the virtually human*. Princeton, NJ: Princeton University Press.

Brooks, F. P. (1998). *Is there any real virtue in virtual reality?* Chapel Hill, NC: University of North Carolina. Retrieved from http://www.cs.unc.edu/~brooks/RealVirtue.pdf.

Brooks, F. P. (1999). What's real about virtual reality? *IEEE Computer Graphics and Applications, 19*(6), 16–27. doi:10.1109/38.799723. ISSN 0272-1716.

Castronova, E. (2001). *Virtual worlds: A first-hand account of market and society on the cyberian frontier* (CESifo Working Paper Series No. 618). Retrieved from http://ssrn.com/abstract=294828

Castronova, E. (2005). *Synthetic worlds: The business and culture of online games*. Chicago: University of Chicago Press. ISBN 0226096262.

Castronova, E. (2008). *A test of the law of demand in a virtual world: Exploring the Petri Dish approach to social science* (CESifo Working Paper Series No. 2355). Retrieved from http://ssrn.com/abstract=1173642

Crooks, A., Hudson-Smith, A., & Dearden, J. (2009). Agent street: An environment for exploring agent based models in Second Life. *Journal of Artificial Societies and Social Simulation, 12*(4), 10. ISSN 1460-7425. Retrieved from http://jasss.soc.surrey.ac.uk/12/4/10.html.

Cruz-Neira, C., Sandin, D., DeFanti, T., Kenyon, R., & Hart, J. (1992). The CAVE audio visual experience automatic virtual environment. *Communications of the ACM, 35*(6), 64–72.

Goldstone, R. L., & Ashpole, B. C. (2004). Human foraging behavior in a virtual environment. *Psychonomic Bulletin and Review, 11*, 508–514.

Goldstone, R. L., Roberts, M. E., & Gureckis, T. M. (2008). Emergent processes in group behavior. *Current Directions in Psychological Science, 17*(1), 10–15.

Goldstone, R. L., Roberts, M. E., & Roberts, M. E. (2005). Knowledge of resources and competitors in human foraging. *Psychonomic Bulletin and Review, 12*(1), 81–87.

Hmeljak, D. (2010). Design and evaluation of a virtual environment infrastructure to support experiments in social behavior. *ProQuest Dissertations and Theses, 328*.

Janssen, M. A., Goldstone, R. L., Menczer, F., & Ostrom, E. (2008). Effect of rule choice in dynamic interactive spatial commons. *International Journal of the Commons, 2*, 288–312.

Novak, T. P. (2007). *Consumer behavior research in Second Life: Issues and approaches*. Association for Consumer Research Pre-Conference, Memphis, TN.

Sutherland, I. E. (1965). The ultimate display. In W. A. Kalenich (Ed.), *Information processing 1965: Proceedings of the IFIP congress 65* (Vol. 2, pp. 506–508). Washington, DC: Spartan Books.

Wadley, G., Gibbs, M., & Ducheneaut, N. (2009). You can be too rich: Mediated communication in a virtual world. OZCHI 2009 Proceedings, Melbourne, Australia.

Weusijana, B. K. A., Svihla, V., Gawel, D., & Bransford, J. (2007). Learning about adaptive expertise in a multi-user virtual environment. In *Proceedings of the Second Life Education Workshop 2007* (pp. 34–39). Chicago: Second Life Community Convention.

Yee, N. (2006). The demographics, motivations and derived experiences of users of massively multi-user online graphical environments. *Presence: Teleoperators and Virtual Environments, 15*(3), 309–329.

Yee, N., & Bailenson, J. N. (2008). A method for longitudinal behavioral data collection in Second Life. *Presence: Teleoperators and Virtual Environments, 17*(6), 594–596.

Yee, N., Bailenson, J. N., Urbanek, M., Chang, F., & Merget, D. (2007). The unbearable likeness of being digital: The persistence of nonverbal social norms in online virtual environments. *Journal of Cyber Psychology and Behavior, 10*, 115–121.

# Review of Educational Research Methods in 3D3C Worlds: Framing the Past to Provide Future Direction

**Dennis Beck and Ross A. Perkins**

## 1 Introduction

The purpose of this chapter is to describe educational research methodologies being used in the investigation and evaluation of desktop virtual world environments (3D3C Worlds). Specifically, it examines how 3D3C Worlds are implemented in educational contexts across multiple subject areas in higher education. We will utilize Ellis' research framework on innovations (2005) and Reeves and Hedberg's research goals (2003) as lenses to examine the state of educational research within 3D3C Worlds. Results will provide a "map" of research methodologies being used according to the first, second, and third levels of research (Ellis, 2005) and according to the six research goals (Reeves & Hedberg, 2003), which will be further described in this chapter. Results will also show methodological gaps that exist in educational research about 3D3C Worlds. Two hypothetical case examples are also provided, which allow for some insight into how virtual world research might be initially conceived and then redirected using the guidelines offered herein. Equipped with such knowledge, researchers can make more intelligent decisions about types of studies and methods of data collection and analysis, resulting in more rigorous studies that cover a broad range of research levels and goals.

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Y. Sivan (ed.), *Handbook on 3D3C Platforms*, Progress in IS,
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## 2 Theoretical Framework

### *2.1 Framework on Educational Innovations*

Ellis (2005) provides a helpful framework from which to view research in new fields of academia.

Level I research is theory building, pure research, or both. It is most commonly conducted in experimental or laboratory settings. Its purpose is to establish a theoretical construct or idea as having some validity. It includes both qualitative and quantitative studies, and may encompass such measures as correlations, descriptive data, and case studies. An important limitation of Level I research is that it is not designed to answer applied questions directly.

Level II research is empirical research, either quantitative, qualitative, or a combination thereof. Its purpose is to determine the efficacy of particular programs or methods in authentic settings. As applied research, it seeks to apply theories and procedures developed in Level I research and provide practical insights that cannot be derived from Level I research. An important limitation to note about Level II research is that it is severely limited in generalizability, but that can be improved by replication studies.

Level III research determines the extent to which a program (curriculum innovation) is successful when its implementation becomes widespread. An example from the field of education would be evaluation studies that determine the overall effects on teachers and students of a particular district or school-wide innovation. Most importantly, this level of research answers the question: Do these results work on a larger scale?

### *2.2 Common Research Goals*

Reeves and Hedberg (2003) classify research into six categories based on the goals of the investigators: theoretical, predictive, interpretivist, postmodern, action, and developmental (See Table 1). Research with theoretical goals is relatively rare given both the requisite experience of the researchers and the longer amount of time it takes to frame this unique type of inquiry. In the field of educational technology, predictive studies are often carried out with a particular innovation in mind, and done so using conditions that are as controlled as possible. Studies driven by predictive goals are prevalent in the field, though their quality is often suspect (Reeves & Hedberg, 2003), and their ultimate usefulness to practice, despite claims of generalizability, tends to be questionable. In contrast to those who approach research with a desire to predict outcomes are those who have interpretivist goals. The major criticism of this kind of inquiry is that the results are seen as “data islands,” in that they cannot be generalized outside of the context in which such studies were conducted. Postmodern research goals, or critical analysis of

**Table 1** Reeve's and Hedberg's research goals

| Research goal | Description |
|---|---|
| Theoretical | To explain "phenomena through the logical analysis and synthesis of theories, principles, and the results of other forms of research such as empirical studies" (Reeves & Hedberg, 2003, p. 270). |
| Predictive | Experimental or quasi-experimental studies in order to test and expand existing theories. |
| Interpretivist | The focus is to "[portray] how education works by describing and interpreting phenomena related to teaching, learning, performance, assessment, social interaction, innovation. . ." (Reeves & Hedberg, 2003, p. 270). The methodological approach tends to be qualitative. |
| Postmodern | A focus on the examination of equity, gender, political and cultural issues as they impact the field. |
| Action | Examine the application of a program, product, or method with the aim to describe, improve, or evaluate its impact or effectiveness. |
| Developmental | Uses the empirical method to examine authentic, complex problems in a realistic context. Additionally, it seeks to provide pragmatic solutions to those who implement educational technology innovations—not just in one context, but multiple contexts. |

phenomena, agendas, practices, and so on is not common in educational technology (Reeves & Hedberg, 2003), but one can occasionally find examples of this type of inquiry. In "action" or "evaluation" research, the "major goal is solving a particular problem in a specific place within a relatively short timeframe" (Reeves & Hedberg, 2003, p. 272). The audience tends to be either practitioners or stakeholders.

Developmental research is advocated by the authors because of its emphasis on solving authentic problems. This type of research blends "best practices" design guidance and hypothetical approaches in a manner that seeks to create solutions to the problems presented. Also known as "formative research," a great deal of emphasis is placed on reflection to test, re-test, and "refine innovative learning environments as well as to define new design principles" (p. 272).

Ellis (2005) framework and Reeves and Hedberg's (2003) research goals will be utilized in this literature review in order to show how studies might be categorized, thereby showing any gaps in types of research and methodologies.

## 3 Method

In order to accomplish this purpose, an extensive search was carried out to locate journal articles in multiple academic fields. Keywords used to search for these articles were combinations of the following: online worlds, virtual worlds, Multi-User Virtual Environments, Massively Multiplayer Online Role Playing Games, Virtual Reality, Second Life, Online worlds, role playing games, Cyberspace, and Immersive Worlds.

**Table 2** Breakdown by academic field

| Academic field | Number of articles | Percentage |
|---|---|---|
| Educational Technology | 48 | 37.8 |
| Computer Science or Information Systems | 12 | 9.45 |
| Virtual Reality/Virtual Worlds/Gaming | 13 | 10.24 |
| Science and Health Education | 10 | 7.87 |
| Human-Computer Interaction | 10 | 7.87 |
| Media and Communications | 9 | 7.09 |
| Psychology or Educational Psychology | 8 | 6.30 |
| Other fields | 6 | 4.72 |
| Social Science and Educational Research | 4 | 3.15 |
| Cognitive Science | 4 | 3.15 |
| Library Science | 3 | 2.36 |

114 articles, 12 presentations, 1 book chapter

Databases searched were ERIC, Academic Search Premier, PsychInfo, Google Scholar, and WilsonWeb. Studies that resulted from this search were refined and focused by using the following criteria: (a) They must deal with 3D3C Worlds, (b) They had to be peer-reviewed, and (c) They must be an actual study, and not a simple description of activities. Dissertations were excluded. The authors of these articles examined different audiences and presented widely differing approaches to research in 3D3C Worlds. From this selection process, 127 studies were chosen which dealt substantively with 3D3C Worlds (see Table 2 for a breakdown by academic field). An article (or presentation) was assigned to a particular field based on the field or academic area that publishes the journal or proceedings. The criteria stated above assured that the works reviewed were (a) representative of works in the different fields, (b) have been central or pivotal to the topic area, and (c) initiated a line of investigation or thinking.

The resulting articles were reviewed in order to describe educational research methodologies being utilized in the investigation and evaluation of 3D3C Worlds. The following data were collected from each study: American Psychological Association (APA) reference for the paper itself, publication outlet, academic field (human computer interaction, computer science, educational technology, etc.), research aim, research questions, website address, data protection measures, opportunity cost of research, data collection methods, type of data collected, independent variables, dependent variables, sampling issues, data analysis method, research innovation level, and research goal level (see Table 3 for a more detailed explanation of each category).

Data were recorded in a spreadsheet and transferred to the NVivo 10.2 software for qualitative analysis. This software was used to help the researchers to organize, analyze, explore, and visualize the data. It helped to uncover subtle connections between data and discover themes that made these connections more explicit. After this, Ellis' framework (2005) and Reeves and Hedberg's research goals (2003) were utilized to show where each study "fits" in research, and to reveal any gaps in types

**Table 3** Type of data collected

| Type of data collected | Justification |
|---|---|
| APA Reference | Categorization purposes |
| Website address (if any) | To provide resources for future researchers |
| Type of entry | Categorized by working paper, peer-reviewed article, or peer-reviewed proceedings |
| Academic field of study | Anthropology, Biology, Education, etc. |
| Research aim | Aims are broad statements of desired outcomes, or the general intentions of the research, which 'paint the picture' of your research proposal. Research aims address the long-term project outcomes, i.e. they should reflect the aspirations and expectations of the research topic |
| Research question(s) | The specific questions that the study sets out to answer. |
| Is security mentioned? In what way? | Discussion involving backup of data, encryption, data access, data integrity, privacy, protection, data storage, etc. are included in order to explore the security of data on the server of the virtual environment |
| Opportunity cost of research? | Is this study funded? How? |
| Type of data collected? | Chat logs, movement data, survey, interviews, etc. |
| Independent variables | What was adjusted to make the change occur? |
| Dependent variables | What was expected to change? |
| Does this study address sampling issues? | The population and sample of virtual world participants is particularly narrow—as regular users do not represent a larger population of students |
| Data analysis method | For example, content analysis, case studies, grounded theory, experimental—ANOVA, ANCOVA, etc. |
| Research innovation level | According to Ellis (2005) |
| Research goal level | According to Reeves and Hedberg (2003) |

of research and methodologies. Data were collected and categorized by multiple researchers in order to ensure trustworthiness and data quality.

# 4 Results

## *4.1 Research Aims and Questions*

The leading research aims and questions focused on affordances of virtual worlds, learning, and instructional strategies. Research that concentrated on affordances examined unique qualities of 3D3C Worlds that allow individuals to perform an action. Explorations that focused on learning typically examined outcomes after participants had some kind of interaction with content matter (e.g. art lessons, math lessons, etc.). Where instructional strategies were investigated, researchers tested the logistics of using one or more approaches to teaching a certain topic within the

**Table 4** Research aims and questions

| Aims/questions | Articles |
|---|---|
| Affordances of VW | 56 |
| Learning | 35 |
| Instructional strategies | 31 |
| Behavior | 21 |
| User attitudes | 20 |
| Interaction | 18 |
| Avatar | 16 |
| Collaboration | 14 |
| Presence | 12 |
| Community | 10 |
| Engagement | 10 |
| Adoption of technology | 8 |
| Motivation | 8 |
| Teachers perceptions | 6 |

environment. In most cases, these three aims were not found in separate studies but co-occurred in a number of the investigations. The qualities of the environment (e.g., desktop 3D objects, avatars, etc.) were studied to determine their impact on learning or instructional strategies.

To a somewhat lesser extent, other research aims and questions focused on participant behavior, user attitudes, interaction, avatars, collaboration and presence. Also worth noting are the studies that focused on community, engagement, technology adoption, motivation, and teacher perceptions (Table 4). Please see Fig. 1 for a visualization of how these differing research aims and questions are related within a study.

While the vast majority of studies avoided using the maligned "media comparison study" framework (comparing learning outcomes in different media conditions), at least five studies used this approach.

## 4.2 How Data Were Collected

Data collection in virtual worlds can be classified into three categories: (1) through mechanisms which capture in-world data, (2) through back-end data recording mechanisms that track user actions, and (3) through data collection tools external to the virtual world that capture users' experiences or input about their experiences. The majority of data that were collected among the 127 studies under review did so through external tools (72 %). These included the use of discussion boards, participant blogs, electronic pre- and post-tests, web-based surveys, physiological measurements (e.g., eye tracking), and interviews. A smaller number of researchers relied on in-world tools to collect data (23 %). The recording of data within a virtual environment often depends on the affordance of the environment itself.

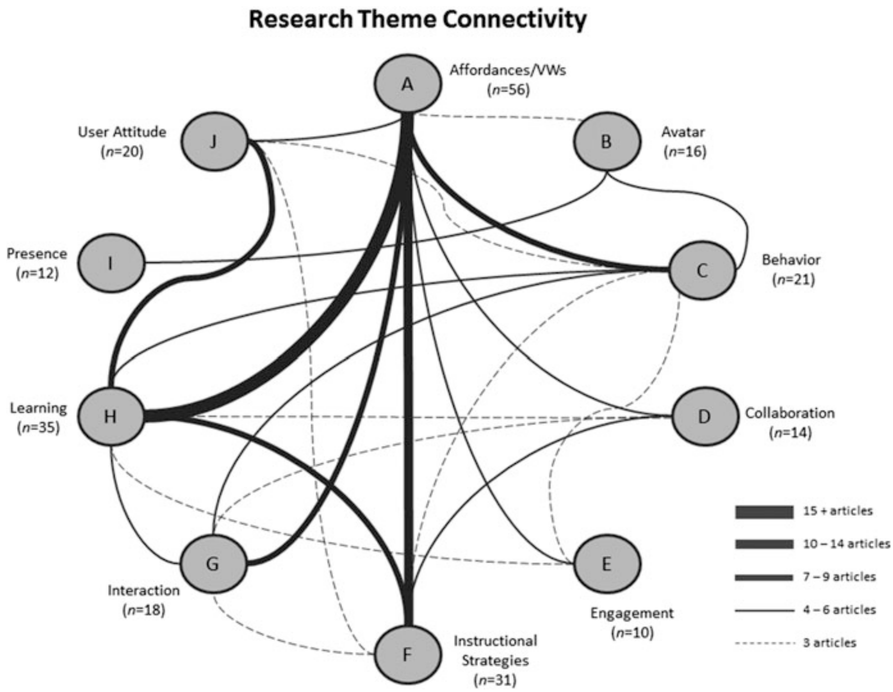


**Fig. 1** Research theme connectivity. The graphic shows the connectivity of the various research themes as well as their representation in the literature

For example, in Second Life, investigators can either make, modify, or use objects that accept "notecards," or act as surveys, or do counts of avatar proximity or length of stay. An examination of the studies found that in-world data mostly was qualitative in scope, including such things as chat logs, images, machinima, or observations either by the researcher or a sensor device. The availability of these data is based on whether or not the researcher has access to the "back-end" of the software (5 %). In the case of Second Life, which has proprietary protections on its data, this is not possible. However, those who run servers (e.g., ActiveWorlds) have a tremendous amount of data available to them, all of which is captured passively—meaning that the participant only needs to interact rather than actively use data collection tools.

## *4.3 What Data Were Collected*

Of the data collected for the various studies, a great deal of it yielded qualitative data or nominally quantitative (surveys). Few studies actually had participants submit to pre-and post-test evaluations of their skills or made objective

**Table 5** Mechanisms used to collected 3D3C World data

| Data collection mechanisms | Occurrences in studies |
|---|---|
| *In-world mechanisms* | |
| Chat Logs | 12 |
| Data (In-world) | 6 |
| Video | 15 |
| Audio recordings or transcripts | 7 |
| Discussions | 8 |
| Images | 9 |
| *External data collection mechanisms* | |
| Surveys or questionnaires | 57 |
| Observations | 47 |
| Interview | 36 |
| Artefacts (external) | 8 |
| Content knowledge and Skills tests | 17 |
| Student reflections | 10 |
| Measurement of physical movement | 4 |
| *Back-end data collection mechanisms* | |
| Data log files (not chat) | 7 |

measurements of movement (physical or avatar). As Table 5 shows, the primary source of data included surveys, interviews, or participant-created artifacts, such as blogs.

Of the articles reviewed, 114 appeared in journals, while 12 were conference proceedings, and one was a handbook chapter.

The journal articles were found in 67 different journals, with approximately 7 % (n = 9) of those appearing in the *British Journal of Educational Technology* and another 7 % in *Computers & Education*. The fields represented by the journals were not limited to educational technology and virtual reality, but included fields of study such as computer and information science, psychology, language studies, and cultural studies.

## 4.4 Sampling

Looking across studies, one sees a fairly consistent theme in sampling in that most participants tend to be solicited based on their participation in a given course (or courses) and tend to be in groups of about 20–50 students total. A number of small, pilot studies or qualitative studies with between approximately five and ten students are also found. When studies have implemented surveys, or where they have studied usage data (from servers), the number of participants is quite high (up to 4000 in one case). There are practically no studies done where true random sampling has been done, and this parallels with the fact that very few empirical studies have been carried out. Interestingly, though all of a user's on-screen actions can be recorded by a server, only a few studies report using these data. In proprietary virtual worlds, such as Second Life, the researcher often does not have access to these data beyond using scripted metrics reported by in-world tools or traffic analysis services. This means that a wealth of data is not analyzable. The samples tend to be one of convenience as students in a course are "captive." Except in only a few studies, participants tend not to be diverse in age or nationality, though gender seems to be equally represented across studies.

## *4.5 Data Analysis*

### 4.5.1 Variables

Of the 127 total sources, 104 included information on the independent variables used. These variables fell into six major categories: Interface/Environment, attitudinal, demographic, cognitive, teaching method, and behavioral. Sixty of the 127 total sources included information on the dependent variables used. These variables fell into eight major categories: Learning, in-world choices/tactics, external behaviors, interaction, perception of experience, presence, flow and engagement, and scientific inquiry (Table 6).

### 4.5.2 Privacy and Security

According to common human subjects' research protocols, researchers need to describe how they have made explicit to participants the risks to data being electronically transmitted and stored. Although participant protections are required for institutional review board applications, a clear explanation of the privacy and security concerns does not appear in many research reports. Only 14 % ($n = 18$ papers) of the studies examined directly discussed data security issues outside of the required need to change participant names (or avatar names) for reporting purposes. The articles that did cover concerns related to security indicated to their participants that public chat in virtual spaces is public, or talked about the logistics for backing-up data on another server.

### 4.5.3 Funding

A total of 29 % ($n = 37$) of the studies were supported by outside agencies, such as the National Science Foundation, private foundations, or consortia. It may seem that there should be more externally funded studies, especially if one compares research on the implementation of other, more established technologies (note: no data are available on the average percentage of peer reviewed publications that are

**Table 6** Independent and dependent variables

| Variable type | Percentage |
|---|---|
| *Independent* | |
| Interface/environment | 35 |
| Attitudinal | 25 |
| Demographic | 21 |
| Cognitive | 7 |
| Behavioral | 7 |
| Teaching method | 5 |
| *Dependent* | |
| Learning | 23 |
| In World choices/tactics | 22 |
| External behaviors | 12 |
| Interaction | 12 |
| Perception of experience | 10 |
| Presence | 8 |
| Flow and engagement | 7 |
| Scientific inquiry | 6 |

funded). This lower level of funding may be due to the relative newness of 3D3C Worlds in research and the overall lack of empirical studies done to date.

### 4.5.4 Virtual Environments Used

The virtual environments reviewed were comprised of commercial MMORPGs (24) such as World of Warcraft, Everquest, and Star Wars Galaxies. The largest group of studies were done using commercially available virtual worlds (92), which included Second Life (47) and Active Worlds (31). It should be noted that in several of these studies, researchers took the Active Worlds platform and customized it for the sake of their own projects (e.g., River City at Harvard and Quest Atlantis at Indiana).

Other virtual environments reviewed included MMORPGs (4) and virtual worlds (7) developed completely within a non-profit institution such as a university. Several of the studies examined two or more virtual environments: text-based virtual worlds (3), institutionally-based game (3), and CAVE-like desktop system (13).

### 4.5.5 Ellis' Levels of Research

As explained in the theoretical framework section, Ellis (2005) explains three levels of research. Level I research is theory building, pure research, or both. Level II research is empirical research, either quantitative, qualitative, or a combination thereof. Level III research determines the extent to which a program (curriculum innovation) is successful when its implementation becomes widespread.

Seventy eight of the studies reviewed were categorized as level I research by Ellis (2005) research framework. This means that 61 % of the studies reviewed focused on theory building, pure research, or both. They were mostly conducted in experimental or artificial lab settings. They included both qualitative and quantitative studies, and used analyses such as correlations, descriptive data, and case studies.

Forty six of the studies reviewed were level II research (Ellis, 2005), indicating that approximately 36 % of the studies were either quantitative or qualitative empirical research or mixed methods. Their purpose was to determine the efficacy of particular programs or methods in authentic settings. This kind of research seeks to apply theories and procedures developed in Level I research and provide practical insights.

About 3 % (three studies) were categorized as level III research (Ellis, 2005). These studies examined a program evaluation in which the researchers examined whether the program is successful when its implementation becomes widespread.

Reeves and Hedberg (2003) hail the importance of developmental research due to its use of the empirical method to examine authentic, complex problems in a realistic context. Interestingly, 6.3 % (8/127) of the reviewed studies were categorized as developmental research, and these eight articles represent research done using four different 3D3C Worlds (River City, Quest Atlantis and EcoMUVE). With that said, the most prevalent research is still being accomplished by researchers with interpretivist (41.7 %, 53/127 studies) and predictive (35.4 %, 45/127 studies) research goals. Other studies were scattered among theoretical (3.9 %, 5/127 studies), action (3.9 %, 6/127 studies), postmodern (2.3 %, 3/127 studies), and mixed goal (6.3 %, 8/127 studies) research goals.

## 5 Discussion and Recommendations

According to Ellis (2005) framework for research in new fields of education, Level III research is almost completely lacking from our study (3/127 studies). This means that there has been virtually no 3D3C World research on the level of program evaluation where it becomes possible to learn the extent to which a program is successful when its implementation becomes widespread. The three studies that were categorized at this level were led by senior educational technology researchers who had customized a 3D3C World for their research. These 3D3C Worlds (River City, EcoMUVE, and Quest Atlantis) could lead the way by converting their application to open source and making it freely available to anyone in exchange for participation in research. This would most likely result in a larger number of teachers, classrooms, and schools playing a part in program evaluation on a grand scale, and would help to answer the question of whether the promising results that have been discovered with less numerous samples will translate to a population of a larger magnitude.

As Reeves and Hedberg (2003) state, postmodern research goals are a rarity in the field of educational technology, and our literature review reflects this (only 2.3 % of articles had a postmodern goal). Atypical to this trend, Beck (2012) examines the influence of student avatar choice on teachers' expectations and perception in his study of over 450 teachers in the 3D3C World Second Life. With that said, 3D3C World researchers should pursue collaborative research opportunities with postmodern, education researchers in order to shed more light on important issues of equity, gender, politics, and culture that impact the field.

The presence of developmental research in 3D3C Worlds is encouraging (8/127 studies, 6.3 %) because of the authentic, complex problems that can be addressed in these type of environments (Reeves & Hedberg, 2003). Moreover, the need to implement these kinds of environments in multiple contexts also lends itself to an approach that tests, retests and refines the 3D3C World as well as to define new design principles. Three major projects (Quest Atlantis, River City, and EcoMUVE) and approximately seven primary researchers are not enough to act as a catalyst for this important research goal. Unfortunately, the opportunity cost of this type of research is high as all of the studies were funded by grants from the National Science Foundation, setting a high bar on the amount of funding, type of institution, and quality of researcher that is able to pursue this type of grant. These researchers should consider converting the proprietary 3D3C Worlds they authored into open-source applications that can be easily utilized by other researchers and institutions who might not have access to NSF funds to create their own. This access could come with a professional development requirement that would enable the current researchers to train others in developmental research skills. Such actions would also likely have an overflow effect of increasing the number and quality of other types of research goals, such as action and critical.

Research with a theoretical research goal was also minimal (5/127, 3.9 %). This is concerning because it points to a lack of logical analysis and synthesis of theories in 3D3C World research. Theoretical research can often provide a map that other types of research can follow. Additionally, other research with differing research goals will lack the focus necessary to make a larger impact without theoretical research. For example, the large amount of predictive (45/127 studies, 35.4 %) and interpretive (53/127 studies, 41.7 %) research may "miss the target" provided by theoretical research. As a result, it is important for 3D3C World researchers to pursue this type of research.

Hew and Cheung (2010) suggest that future research should provide a rich, thick description of the methodology, including the duration of the study, interobserver and intraobserver agreement reliability and effect sizes so that findings can be adequately interpreted. The APA Task Force stressed that researchers should provide some effect-size estimate such as Cohen's $d$ when reporting a $p$-value because reporting and interpreting effect sizes are essential to high quality, empirical research (Wilkinson, 1999). Kotrlik and Williams (2003) argued that reporting effect size allows a researcher to judge the magnitude of the differences present between groups, thus increasing the capability of the researcher to judge the practical significance of the results derived.

Future studies should also be longitudinal in nature, extending the duration to perhaps more than 1 year. Doing longitudinal studies provides researchers with the opportunity to examine not only whether students' and teachers' perceptions of virtual worlds undergo change but also whether there are any detrimental effects of using virtual world environments over a long period of time, which has not been investigated up to this point.

Our research showed that there are already sufficient level I research studies (78/127) and a growing number of Level II research studies (46/127). Future research should continue to focus on Level II research that determines the efficacy of particular programs or methods in authentic settings. This level of research is a prerequisite for Level III research and is one of the reasons why very few Level III studies have been conducted (3/127).

Most of the research being done with 3D3C Worlds has predictive (35.4 %, 45/127 studies) and interpretive (41.7 %, 53/127 studies) research goals. Researchers who are seeking to find areas that need to be addressed in this field should consider 3D3C World research with theoretical, action, postmodern, and developmental research goals. Because of the pressing need for innovation and thoughtful technology integration in authentic learning environments such as schools, action and developmental research goals should receive particular emphasis (Reeves & Hedberg, 2003). Implementation and evaluation studies, however, cannot be initiated simply because a gap exists as a number of antecedents must necessarily be in place for such studies to be possible.

As noted previously, Level III research is on the level of program evaluation where it becomes possible to learn the extent to which a program is successful when its implementation becomes widespread. Will there ever be a situation where there are enough Level III studies to provide sufficient evidence? Or do the logistical circumstances such as large start-up costs, lack of authentic implementation context, labor, and subject matter expertise prohibit such a situation from ever occurring? Future research should strive to overcome these logistical difficulties through collaboration with the individuals who are already performing Level III research, and they should also seek to form new partnerships with other researchers who are interested in Level III research.

## 6 Conclusion

Our interest in this study was to catalogue the diverse means that researchers in the educational community have used in 3D3C studies. We did not set out to compare and contrast conclusions of studies or draw out general principles from those studies. The data we gathered point to a relatively immature field even if some specific efforts have a solid empirical foundation and have in some respects become seminal works. While other literature reviews about 3D3C studies might seek to draw out themes and trends, we would assert based on our investigation that there are few solid conclusions about learning in 3D3Cs that one can confidently make at this time. This is not due to a lack of quality found in selected efforts, but there is simply not yet a critical mass of research. Numbers alone will not help, though more studies are of course necessary. Our study makes clear that the "critical mass" needs to be made up of more diverse and deeper research than is currently found.

Initiating research in a relatively new field in any discipline can be fraught with peril. Traditional methods of data collection and analysis may not automatically integrate into the new technological environment. Unproven methods may appear to work better, but usage of these methods will lengthen the study cycle. Moreover, use of unproven methods may be shunned by more well-known journals, thus relegating the research to less impactful journals and potentially affecting the professional outlook for scholars. It is therefore important to approach a new field of educational technology with as much knowledge as possible of the research methodologies being used. This is especially true in the relatively new field of 3D3C Worlds, where pioneering research is being done without much knowledge of what has been done and what works well.

It is far too easy to perform research that does not impact practice, yet this is consistently the call among leading scholars in the field (Southerland, Gadsden, & Herrington, 2014). One of the keys to doing research that impacts practice is to follow a research agenda that targets under-researched purposes and variables, uses unique methods, and aligns with under-addressed research levels and goals. Should others use the analysis we provide, 3D3C World researchers can focus on addressing important questions in the field.

## Appendix: List of Virtual World Articles Analyzed for This Paper

Ahmad, M. A., Huffaker, D., Wang, J., Treem, J., Kumar, D., Poole, M. S., & Srivastava, J. (2010). The many faces of mentoring in an MMORPG. *Proceedings of the 2010 I.E. Second International Conference on Social Computing*, 270–275.

Albert, G., Renaud, P., Chartier, S., Renaud, L., Sauvé, L., & Bouchard, S. (2005). Scene perception, gaze behavior, and perceptual learning in virtual environments. *CyberPsychology & Behavior*, *8*(6), 592–600. doi:10.1089/cpb.2005.8.592

Bailenson, J., Yee, N., Blascovich, J., Beall, A., Lundblad, N., & Jin, M. (2008). The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context. *Journal of the Learning Sciences*, *17*(1), 102–141. doi:10.1080/10508400701793141

Bakardjieva, M. (2003). Virtual togetherness: An everyday-life perspective. *Media Culture Society*, *25*, 291–313.

Baker, S., Wentz, R., & Woods, M. (2009). Using virtual worlds in education: Second Life as an educational tool. *Teaching of Psychology*, *36*(1), 59–64. doi:10.1080/00986280802529079.

Barab, S., Sadler, T.D., Heiselt, C., Hickey, D., Zuiker, S. (2010). Erratum to: Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, *19*, 387–407.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, content, and context. *Educational Researcher*, *39*(7), 525–536.

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D. & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, *16*(1), 59–82.

Barab, S. A., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S. J., & Warren, S. (2009). Transformational play as a curricular scaffold: Using videogames to support science. *Education Journal of Science Education & Technology*, *18*, 305–320.

Barab, S., Dodge, T., Gentry, E., Saleh, A., & Pettyjohn, P. (2011). Uganda's road to peace may run through the river of forgiveness: Designing playable fictions to teach complex values. (pp. 312–333). In K. Schrier & D. Gibson (ed.) Ethics and game design: Teaching values through play (Vol. II). IGI Global, Hershey, PA.

Barab, S., Dodge, T., Thomas, M. K., Jackson, C., & Tuzun, H. (2007). Our designs and the social agendas they carry. *The Journal of the Learning Sciences*, *16*(2), 263–305.

Barab, S., Pettyjohn, P., Gresalfi, M., Volk, C., & Solomou, M. (2012). Game-based curriculum and transformational play: Designing to meaningfully position person, content, and context. *Computers & Education, 58*, 518–533.

Barab, S., Zuiker, S., Warren, S., Hickey, D., Ingram-Goble, A., Kwon, E., et al. (2007). Situationally embodied curriculum: Relating formalisms and contexts. *Science Education*, *91*(5), 750–782.

Barab, S. A., Thomas, M., Dodge, T., Carteaux, R., & Tuzun. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development*, *53*(1): 86–107.

Black, E. W., Ferdig, R. E., DiPietro, J. C., Liu, F., Whalen, B. (2008). Visual analyses of the creation of avatars. *International Journal of Gaming and Computer-Mediated Simulations*, *1*(1), 90–107.

Black, R. W. (2010). The language of Webkinz : Early childhood literacy in an online virtual world. *Childhood A Global Journal Of Child Research*, *2* (May), 7–24.

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*(4), 233–245.

Bowers, J., Pycock, J. & O'Brien, J. (1996). Talk and embodiment in collaborative virtual environments. In Proceedings of the *SIGCHI Conference on Human Factors in Computing Systems: Common Ground*. New York: ACM Press, 58–65.

Burgess, M. L. (2010). Teaching and learning in second life: Using the community of inquiry (COI) model to support online instruction with graduate students in instructional technology. *The Internet and Higher Education (1096-7516)*, 13 (1/2), 84.

Caplan, S., Williams, D., & Yee, N. (2009). Problematic Internet use and psychosocial well-being among MMO players. *Computers in Human Behavior, 25*, 1312–1319.

Carter, D. M. (2004). Living in virtual communities: Making friends online. *Journal of Urban Technology, 11*(3), 109–125.

Casanueva, J. S. & Blake, E. H. (2001). The effects of avatars on co-presence in a collaborative virtual environment. Annual Conference of the South African...

Castronova, E. (2009). A test of the law of demand in a virtual world: Exploring the petri dish approach to social science. *International Journal of Gaming and Computer-mediated Simulations (1942-3888),* 1 (2).

Castronova, E. (2001). Virtual worlds: A first-hand account of market and society on the cyberian frontier. Munich, Germany.

Cerrato, T., & Waern, Y. (2000). Chatting and learning to chat in collaborative virtual environments. *M/C - A Journal of Media and Culture, 3*(4). Retrieved March 25, 2010 from http://journal.media-culture.org.au/0008/learning.php

Chang, V., Gütl, C., Kopeinik, S., & Williams, R. (2009). Evaluation of collaborative learning settings in 3D virtual worlds. *International Journal of Emerging Technologies in Learning, (S3*), 6–17. doi:10.3991/ijet.v4s3.1112

Cheal, C. (2009). Student perceptions of a course taught in second life. *Innovate 5* (5). Retrieved May 29, 2009 from http://www.innovateonline.info/index.php?view=article&id=692. The article is reprinted here with permission of the publisher, The Fischler School of Education and Human Services at Nova Southeastern University.

Chen, X., Siau, K., & Nah, F Fui-Hoon (2009). 3-D virtual worlds and higher education. *AMCIS 2009 Proceedings*. Paper 734. Retrieved from http://aisel.aisnet.org/amcis2009/734

Chi-Anh La, P. M. (2008). Characterizing user mobility in second life. *WOSP'08*: Proceedings of the first workshop on online social networks.

Choi, B., & Baek, Y. (2011). Exploring factors of media characteristic influencing flow in learning through virtual worlds. *Computers & Education, 57*(4), 2382–2394.

Chung, D. (2005). Something for nothing: Understanding purchasing behaviors in social virtual environments. *CyberPsychology & Behavior, 8*(6), 538–554.

Clark, M. (2009). Genome island: A virtual science environment in second life. *Innovate 5* (6). Retrieved April 3, 2010 from http://www.innovateonline.info/index.php?view=article&id=562

Clarke, J., Dede, C., Ketelhut, D. J., & Nelson, B. (2006). A design-based research strategy to promote scalability for educational innovations. *Educational Technology, 46(*3), 27–36.

Cochrane, K. (2006). Case study: International Spaceflight Museum. Proceedings of the *First Second Life Education Workshop, Part of the 2006 Second Life Community Convention*, 13–18, 2–5.

Conati, C., & Merten, C. (2007). Eye-tracking for user modeling in exploratory learning environments: An empirical evaluation. *Knowledge-Based Systems, 20* (6), 557–574. doi:10.1016/j.knosys.2007.04.010

de Byl, P. (2009). Making web 3D less scary: Toward easy-to-use web 3D e-learning content development tools for educators. *Innovate 5* (5). Retrieved April 3, 2010 from http://www.innovateonline.info/index.php?view=article&id=554

de Freitas, S., & Neumann, T. (2009). The use of 'exploratory learning' for supporting immersive learning in virtual environments. *Computers & Education, 52*(2), 343–352. doi:10.1016/j.compedu.2008.09.010

De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G. D., & Poulovassilis, A. (2010). Learning as immersive experiences: using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology, 41*(1), 69–85.

Delwiche, A. (2006). Massively multiplayer online games (MMOs) in the new media classroom. *Educational Technology & Society, 9*(3), 160–172.

Deutschmann, M., & Panichi, L. (2009). Talking into empty space? Signaling involvement in a virtual language classroom in Second Life. *Language Awareness, 18,* 310–328.

Dickey, M. D. (2005). Three-dimensional virtual worlds and distance learning: two case studies of active worlds as a medium for distance education. *British Journal of Educational Technology, 36*(3), 439–451.

Dickey, M. D. (2010). The pragmatics of virtual worlds for K-12 educators: investigating the affordances and constraints of active worlds and Second Life with K-12 in-service teachers. *Educational Technology Research & Development, 59*(1), 1–20.

Dickey, M.D. (2003). Teaching in 3D: Pedagogical affordances and constraints of 3D virtual worlds for synchronous distance learning, *Distance Education 24* (1) (2003), pp. 105–121.

Dodge, T., Barab, S., & Stuckey, B. (2008). Children's sense of self: Learning and meaning in the digital age. *Journal of Interactive Learning Research (2008)* 19 (2), 225–249.

Edirisingha, P., Nie, M., Pluciennik, M., & Young, R. (2009). Socialisation for learning at a distance in a 3-D multi-user virtual environment. *British Journal of Educational Technology, 40*(3), 458–479. doi:10.1111/j.1467-8535.2009.00962.x

Elliott, J., Adams, L. & Bruckman, A. (2002). No magic bullet: 3D video games in education. Proceedings of ICLS 2002. Seattle, WA. Retrieved April 18, 2010 from http://www.cc.gatech.edu/~asb/papers/aquamoose-icls02.pdf

Falloon, G. (2010). Using avatars and virtual environments in learning: What do they have to offer? *British Journal of Educational Technology, 41*(1), 108–122. doi:10.1111/j.1467-8535.2009.00991.x

Fassbender, E., Richards, D., Bilgin, A., Thompson, W. F., & Heiden, W. (2012). VirSchool: The effect of background music and immersive display systems on memory for facts learned in an educational virtual environment. *Computers & Education, 58*(1), 490–500. Elsevier Ltd.

Gillath, O., McCall, C., Shaver, P., & Blascovich, J. (2008). What Can Virtual Reality Teach Us About Prosocial Tendencies in Real and Virtual Environments? Media Psychology, 11(2), 259–282. doi:10.1080/15213260801906489

Harrison, R. (2009). Excavating second life: Cyber-archaeologies, heritage and virtual communities. *Journal of Material Culture, 14*(1), 75–106.

Heldal, I. (2007). The impact of social interaction on usability for distributed virtual environments. *The International Journal of Virtual Reality, 2007,* 6(3):45–54.

Hill, V. (2009). Libraries and immersive learning environments unite in second life. *Library Hi tech (0737-8831)*, 27(3), 338.

Hindmarsh, J., Fraser, M., Heath, C., Benford, S. & Greenhalgh, C. (1998). Fragmented interaction: establishing mutual orientation in virtual environments. In proceedings of the *1998 ACM Conference on Computer Supported Cooperative Work,* (pp. 217–226). New York, NY: ACM Press.

Hou, H.-T. (2010). Applying lag sequential calculation and social network analysis to detect learners' behavioral patterns and generate automatic learning feedback-scenarios for educational MMORPG games. *2010 Third IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, 213-215*. IEEE. Retrieved from http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5463772

Hou, H-T. (2012). Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG). *Computers & Education, 58*, 1125–1233.

Huang, Y-C, Backman, S. J., Backman, K. F. (2010). Student attitude toward virtual learning in Second Life: A flow theory approach. *Journal of Teaching in Travel & Tourism, 10*(4), 312–334

Jamaludin, A., Chee, Y., & Ho, C. (2009). Fostering argumentative knowledge construction through enactive role play in "Second Life". *Computers & Education, 53*(2), 317–329.

Jarmon, L., Lim, K. Y. T., Carpenter, B. S., & Jensen, K. (2009). Pedagogy, Education and Innovation in 3-D virtual worlds. April 2009. Innovation, 2(1), 4–28.

Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education,* 53(1), 169–182. doi:10.1016/j.compedu.2009.01.010

Jennings, N., & Collins, C. (2007). Virtual or virtually u: Educational institutions in Second Life. *International Journal of Social Sciences, 2*(3), 180–186.

Jin, Seung-A. (2009). Modality effects in Second Life: The mediating role of social presence and the moderating role of product involvement. *Cyberpsychology & Behavior, 12*(6) doi 10.1089/cpb.2008.0273

Johnson, N., Xu, C., Zhao, Z., Ducheneaut, N., Yee, N., Tita, G., & Hui, P. (2009). Human group formation in online guilds and offline gangs driven by a common team dynamic. *Physical Review E, 79*, 066117.

Jones, J., Morales, C., & Knezek, G. (2005). 3-dimensional online learning environments: examining attitudes toward information technology between students in Internet-based 3-dimensional and face-to-face classroom instruction. *Educational Media International, 42*(3), 219–236. doi:10.1080/09523980500161254

Jung, Y., & Kang, H. (2010). User goals in social virtual worlds: A means-end chain approach. *Computers in Human Behavior, 26*(2), 218–225.

Kafai, Y. B., Cook, M. S., & Fields, D. A. (2009). Blacks deserve bodies too!: Design and discussion about diversity and race in a tween virtual world. *Games and Culture, 5*(1), 43–63.

Ke, Z., Shiang Wuu, P., & Jui-long, H. (2009). Online collaborative learning in a project-based learning environment in Taiwan: a case study on undergraduate students' perspectives. *Educational Media International, 46*(2), 123–135. doi:10.1080/09523980902933425

Ketelhut, D. J. (2007). The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in River City, a multi-user virtual environment. *The Journal of Science Education and Technology, 16*(1), 99–111.

Kongmee, I., Strachan, R., Pickard, A., & Montgomery, C. (2011). Moving between virtual and real worlds: Second language learning through massively multiplayer online role playing games (MMORPGs). *3rd Computer Science and Electronic Engineering Conference* CEEC (2011), pp. 13–18.

Lee, O., & Shin, M. (2004). Addictive consumption of avatars in cyberspace. *Cyberpsychology & Behavior, 7*(4), 417–420.

Lisk, T. C., Kaplancali, U. T., & Riggio, R. E. (2011). Leadership in multiplayer online gaming environments. *Simulation & Gaming, 42*(1), 1–17.

Livingstone, D., Kemp, J., & Edgar, E. (2008). From multi-user virtual environment to 3D virtual learning environment. *ALT-J: Research in Learning Technology, 16*(3), 139–150. doi:10.1080/09687760802526707

Luo, L., & Kemp, J. (2008). Second Life: Exploring the Immersive Instructional Venue for Library and Information Science Education. *Journal of Education for Library and Information Science 49*(3), 147–166.

Mahon, J., Bryant, B., Brown, B., & Kim, M. (2010). Using Second Life to enhance classroom management practice in teacher education. *Educational Media International, 47*(2), 121–134. Routledge. Retrieved from 10.1080/09523987.2010.492677

Mason, H, & Moutahir, M. (2006). Multidisciplinary experiential education in Second Life: A global approach. Proceedings of the *First Second Life Education Workshop*, part of the *2006 Second Life Community Convention,* 30–34.

Matusitz, J. (2005). Deception in the virtual world: A semiotic analysis of identity. *Journal of New Media and Culture, 3(*1), 54–63.

Metcalf, S. J., Clarke, J. & Dede, C. (2009). Virtual worlds for education: River City and EcoMUVE. *Media In Transition International Conference,* MIT, April 24–26, 2009, Cambridge, MA.

Metcalf, S., Kamarainen, A., Tutwiler, M. S., and Grotzer, T. (2011). Ecosystem science learning via multi-user virtual environments. *International Journal of Gaming and Computer-Mediated Simulations, 3*(1), 86–90.

Meyer, P., & Swatman, P. (2009).Virtual worlds: The role of rooms and avatars in virtual teamwork. *AMCIS 2009 Proceedings*. Paper 384. Retrieved from http://aisel.aisnet.org/amcis2009/384

Meyers, E. (2009). Tip of the iceberg: Meaning, identity, and literacy in preteen virtual worlds. *Journal of Education for Library & Information Science, 50*(4), 226–236.

Moore, R.J., Ducheneaut, N. & Nickell, E. (2007). Doing virtually nothing: Awareness and accountability in massively multiplayer online worlds. *Computer Supported Cooperative Work, 16*(3), 265–305.

Moreno, R., & Mayer, R. E. (2004). Personalized messages that promote science learning in virtual environments. *Journal of Educational Psychology, 96*(1), 165–173.

Nam, C., & Shu, J., Chung, D. (2008). The roles of sensory modalities in collaborative virtual environments (CVEs). *Computers in Human Behavior, 24(*4), 1404–1417. doi:10.1016/j.chb.2007.07.014

Nelson, B., Ketelhut, D. J., Clarke, J., Bowman, C., & Dede, C. (2005). Design-based research strategies for developing a scientific inquiry curriculum in a multi-user virtual environment. *Educational Technology, 45*(1), 21–27.

Nelson, B. (2007). Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment. *The Journal of Science Education and Technology, 16*(1), 83–97.

Nowak, K. L. (2004). *Journal of Computer-Mediated Communication,9*(2). Retrieved May 14, 2010, from http://jcmc.indiana.edu/vol9/issue2/nowak.html

Oliver, M., & Carr, D. (2009). Learning in virtual worlds: Using communities of practice to explain how people learn from play. *British Journal of Educational Technology, 40*(3), 444–457. doi:10.1111/j.1467-8535.2009.00948.x

Oliverio, J. C., & Beck, D. (2009). Enhanced interaction in mixed social environments. In R.F. Ferdig (Ed.), *Handbook of Research on Effective Electronic Gaming in Education* (pp. 146–162). Hershey, PA: Information Science Publishing.

Omale, N., Hung, W., Luetkehans, L., & Cooke-Plagwitz, J. (2009). Learning in 3-D multiuser virtual environments: Exploring the use of unique 3-D attributes for online problem-based learning. *British Journal of Educational Technology, 40*(3), 480–495. doi:10.1111/j.1467-8535.2009.00941.x

Pérez-García, M. (2009). MUVEnation: A European peer-to-peer learning programme for teacher training in the use of MUVEs in education. *British Journal of Educational Technology, 40*(3), 561–567. Retrieved April 21, 2010 from ProQuest Central. (Document ID: 1680515021).

Peterson, M. (2006). Learner interaction management in an avatar and chat-based virtual world. *Computer Assisted Language Learning, 19*(1), 79–103.

Petrakou, A. (2010). Interacting through avatars: Virtual worlds as a context for online education. *Computers & Education, 54*(4), 1020–1027. doi:10.1016/j.compedu.2009.10.007

Pfeil, U., Ang, C., & Zaphiris, P. (2009). Issues and challenges of teaching and learning in 3D virtual worlds: real life case studies. *Educational Media International, 46*(3), 223–238. doi:10.1080/09523980903135368

Rappa, N. A., Kok, D., Yip, H., & Baey, S. C. (2008). The role of teacher, student and ICT in enhancing student engagement in multiuser virtual environments. *British Journal of Educational Technology*, 1–9.

Roussou, M, Oliver, M., & Slater, M. (2006). The virtual playground: an educational virtual reality environment for evaluating interactivity and conceptual learning. *J Virt Real 10*(3–4), 227–240. Retrieved http://www.springerlink.com/content/8ptk37170086544h/, published online: 5 October 2006.

Roussou, M., Oliver, M., & Slater, M. (2008). Exploring activity theory as a tool for evaluating interactivity and learning in virtual environments for children. *Cognition, Technology & Work, 10*(2), 141–153. doi:10.1007/s10111-007-0070-3

Sadler, T., Barab, S., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education 37*(4): 371–91.

Sanchez, J. (2007). Second Life: An interactive qualitative analysis. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference 2007* (pp. 1240–1243). Chesapeake, VA: AACE.

Sardone, N., & Devlin-Scherer, R. (2008). Teacher candidates' views of a multiuser virtual environment (MUVE). *Technology, Pedagogy & Education, 17*(1), 41–51. doi:10.1080/14759390701847484

Savin-Baden, M. (2010). Changelings and shape shifters? Identity play and pedagogical positioning of staff in immersive virtual worlds. *London Review of Education,* 8(1), 25–38.

Savin-Baden, M., Tombs, C., Poulton, T., Conradi, E., Kavia, S., Burden, D., & Beaumont, C. (2011). An evaluation of implementing problem-based learning scenarios in an immersive virtual world. *International Journal of Medical Education, 2,* 116–124. Retrieved from http://www.ijme.net/archive/2/implementing-and-evaluating-virtual-scenarios/

Sayers, H. (2004). Desktop virtual environments: a study of navigation and age. *Interacting with Computers, 16*(5), 939–956. doi:10.1016/j.intcom.2004.05.003

Schiller, S. (2009). Practicing learner-centered teaching: Pedagogical design and assessment of a Second Life project. *Journal of Information Systems Education, 20*(3), 369–381.

Schroeder, R., Heldal, I., & Tromp, J. (2006). The usability of collaborative virtual environments and methods for the analysis of interaction. *Presence: Teleoperators & Virtual Environments, 15*(6), 655–667.

Shen, J., & Eder, L. (2009). Intentions to use virtual worlds for education. *Journal of Information Systems Education, 20(*2), 225–233. Retrieved April 20, 2010, from ABI/INFORM Global. (Document ID: 1755224811).

Siyahhan, S., Sasha, A., Barab, S.A., & Downton, M.P. (2010). Using activity theory to understand intergenerational play: The case of Family Quest. *Computer-Supported Collaborative Learning, 5,* 415–432.

Siyahhan, S., Barab, S. A., & James, C. (2012). Youth and the ethics of identity play in virtual spaces. *Journal of Interactive Learning Research, 22*(1).

Steinkuehler, C. A. (2004). Learning in massively multiplayer online games. In Kafai, Y. B., Sandoval, W. A., Enyedy, N., Nixon, A. S. & Herrera, F. (Eds.), *Proceedings of the 6th International Conference of the Learning Sciences*, (pp. 521–528). Mahwah, NJ: Erlbaum.

Suh, S., Kim, S. W., & Kim, N. J. (2010). Effectiveness of MMORPG-based instruction in elementary English education in Korea. *Journal of Computer Assisted Learning, 26*(5), 370–378.

Sullivan, F. R. (2009). Risk and responsibility: A self-study of teaching with Second Life. *Journal of Interactive Learning Research 20*(3): 337–357. Retrieved April 4, 2010 from Education Research Complete. EBSCO.

Susaeta, H., Jimenez, F., Nussbaum, M., Gajardo, I., Andreu, J. J., & Villalta, M. (2010). From MMORPG to a classroom multiplayer presential role playing game. *Educational Technology & Society, 13*(3), 257–269. Citeseer.

Sutcliffe, A., & Alrayes, A. (2012). Investigating user experience in Second Life for collaborative learning. *International Journal of Human-Computer Studies, 70* (7) (July 2012).

Talamo, A., & Ligorio, B. (2001). Strategic identities in cyberspace. *Cyberpsychology and Behavior, 4*(1), 109–122.

Twining, P. (2009). Exploring the educational potential of virtual worlds—Some reflections from the SPP. *British Journal of Educational Technology, 40*(3), 496–514. doi:10.1111/j.1467-8535.2009.00963.x

Varvello, M., Picconi, F., Diot, C., & Biersack, E. (2008). Is there life in Second Life? International Conference On Emerging Networking Experiments And Technologies Proceedings of the 2008 ACM CoNEXT Conference.

Vogel, D., Guo, M., Zhou, P.,Tian, S. & Zhang, J. (2008). In search of Second Life nirvana. *Issues in Informing Science and Information Technology, 5*(2008).

Wagner, C., & Ip, R. (2009). Action learning with Second Life - a pilot study. *Journal of Information Systems Education, 20*(2), 249–258. Retrieved April 20, 2010, from ProQuest Central. (Document ID: 1755224831).

Warren, S., Barab, S., & Dondlinger, M. (2008). A MUVE towards PBL writing: Effects of a digital learning environment designed to improve elementary student writing. *Journal of Research on Technology in Education, 41*(1). 487–505.

Warren, S., Dondlinger, M., Stein, R., & Barab, S. (2009). Educational game as supplemental learning tool: Benefits, challenges, and tensions arising from use in an elementary school classroom. *Journal of Interactive Learning Research, 20* (4).

Warren, S., Stein, R., Dondlinger, M., & Barab, S. (2009). A look inside a design process: Blending instructional design and game principles to target writing skills. *Journal of Educational Computing Research, 40*(3).

Webb, S. (2001). Avatar culture: Narrative, power and identity in virtual world environments. Information. *Communication and Society, 4*(4), 560–594.

Weusijana, B., Svihla, V., Gawel, D., & Bransford, J. (2009). MUVEs and experiential learning: Some examples. *Innovate 5(*5). Retrieved from http://www.innovateonline.info/index.php?view=article&id=702

Wrzesien, M., & Alcañiz Raya, M. (2010). Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project. *Computers & Education, 55*(1), 178–187.

Yee, N. (2006). The demographics, motivations and derived experiences of users of Massively-Multiuser Online Graphical Environments. *Presence: Teleoperators and Virtual Environments, 15*, 309–329.

Yee, N., Bailenson, J.N., Urbanek, M., Chang, F., & Merget, D. (2007). The unbearable likeness of being digital; The persistence of nonverbal social norms in online virtual environments. *Cyberpsychology and Behavior, 10*, 115–121.

Yee, N., & Bailenson, J. (2008). A method for longitudinal behavioral data collection in Second Life. *Presence: Teleoperators & Virtual Environments, 17*(6), 594–596.

Yee, N., & Bailenson, J. N. (2009). The difference between being and seeing: The relative contribution of self perception and priming to behavioral changes via digital self-representation. *Media Psychology, 12*, 195–209. DOI: 10.1080/15213260902849943

Yuanqiong, W., & Braman, J. (2009). Extending the classroom through Second Life. *Journal of Information Systems Education, 20*(2), 235–247.

## References

Beck, D. (2012). The influence of gender and ethnicity of student avatars on teacher's expectations and perceptions. *International Journal of Gaming and Computer Mediated Simulations, 4*(1), 1–24.

Ellis, A. K. (2005). *Research on educational innovations* (4th ed.). Princeton, NJ: Eye on Education, Inc.

Hew, K., & Cheung, W. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55.

Kotrlik, J. W., & Williams, H. A. (2003). The incorporation of effect size in information technology, learning, and performance research. *Information Technology, Learning, and Performance Journal, 21*(1), 1.

Reeves, T. C., & Hedberg, J. G. (2003). *Interactive learning systems evaluation*. Englewood Cliffs, NJ: Educational Technology Publications.

Southerland, S. A., Gadsden, V. L., & Herrington, C. D. (2014). Editor's introduction: What should count as quality in educational research? Continuing the discussion. *Educational Research, 43*(1), 7–8.

Wilkinson, L. (1999). Statistical methods in psychology journals: Guidelines and explanations. *American psychologist, 54*(8), 594.

# Linguistic and Multilingual Issues in 3D3C Worlds

**Samuel Cruz-Lara, Alexandre Denis, Nadia Bellalem, and Lotfi Bellalem**

## 1 Linguistic and Multilingual Issues in Virtual Worlds

3D3C worlds and serious games are fascinating good examples of fields of development where applications offering linguistic and, in particular, multilingual support have become an absolute necessity. We may obviously include localization (i.e., adapting the natural language used by the graphical user interface), and automatic translation (i.e., using some specific software to translate text or speech from one natural language to another). But beyond that "classical multilingual support", we may also include interactive and non-intrusive multilingual tools like a linguistic enhanced chat (Cruz-Lara, Bellalem, Bellalem, & Osswald, 2009), as well as natural language processing-based activities, such as e-learning—in particular language learning—(Amoia, 2011; Amoia, Gardent, & Perez-Beltrachini, 2011), conversation support in serious games (Bretaudière, Cruz-Lara, & Rojas Barahona, 2011), and even sentiment analysis and emotion detection based on textual information.

For example: today, talking to people via a textual chat interface has become very usual. Many web applications have an embedded chat interface, with a varying array of features, so that the users can communicate from within these applications. But all applications have their own peculiarities, and their chats also serve various requirements. A distinctive feature of virtual worlds is that people are more likely to converse interactively with other people who cannot speak their native language. In such cases, the need for some kind of "innovative" multilingual support becomes obvious. As we will explain in the following sections, a linguistic enhanced chat interface with multilingual features can meet these requirements. Moreover, such an interface can be turned into an advantage for people who want to improve their foreign language skills in virtual life situations.

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As most of our ongoing research activities are devoted to sentiment analysis and emotion detection from textual information, these two fields will be described in a much more detailed way. We will also dedicate special attention to standardization issues, in particular, in the framework of sentiment analysis and emotion detection. An extensive presentation of the "MultiLingual Information Framework" standard (MLIF) (ISO 24616:2012) that we have developed and that has become in 2012 an ISO international standard may be found in (Cruz-Lara et al., 2011; Cruz-Lara, Francopoulo, Romary, & Semar, 2010). In this paper we will show how other, a priori, non-linguistics related standards such as EmotionML (i.e., a W3C proposed recommendation for the annotation and representation of emotions) that could be successfully associated to linguistic and multilingual issues in virtual worlds and serious games.

## 2 Classical Multilingual Issues

### *2.1 Globalization: Localization and Internationalization*

As the former LISA association (Localization Industry Standards Association; http://www.gala-global.org/lisa-oscar-standards) explained, Globalization can best be thought of as a cycle rather than a single process, as shown in Fig. 1.

In this view, the two primary technical processes that comprise globalization—internationalization and localization—are seen as part of a global whole:

Internationalization encompasses the planning and preparation stages for a product in which support for global market is built in by design. This process means that all cultural assumptions are removed and any country- or language-specific content is stored externally to the product so that it can be easily adapted.

Localization refers to the actual adaptation of the product for a specific market. It includes translation, adaptation of graphics, adoption of local currencies, use of proper forms for dates, addresses, and phone numbers, and many other details, including physical structures of products in some cases.

### *2.2 Automatic Translation*

Automatic or Machine Translation (MT) is a sub-field of computational linguistics that investigates the use of computer software to translate text or speech from one natural language to another. At its basic level, MT performs simple substitution of words in one natural language for words in another. Using corpus techniques, more complex translations may be attempted, allowing for better handling of differences in linguistic typology, phrase recognition, and translation of idioms, as well as the isolation of anomalies.

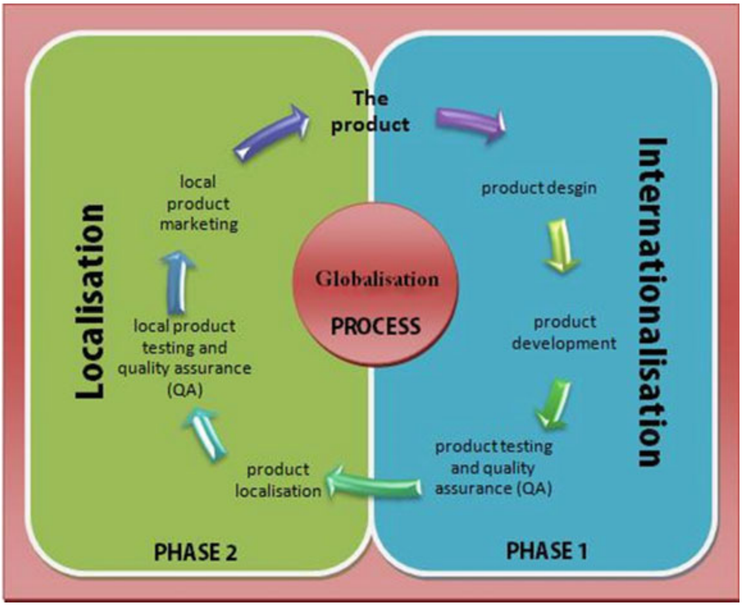



**Fig. 1** The globalization process (http://commons.wikimedia.org/)

Current MT software often allows for customization by domain or profession (such as weather reports)—improving output by limiting the scope of allowable substitutions. This technique is particularly effective in domains where formal or formulaic language is used. It follows then that machine translation of government and legal documents more readily produces usable output than conversation or less standardized text (Wikipedia. http://en.wikipedia.org/wiki/Machine_translation).

## 3 Innovative Multilingual and Linguistic Issues

In this section we will present several innovative multilingual and linguistic issues that may be successfully associated with 3D3C worlds.

### *3.1 Interactive and Linguistic Chat-Based Communication*

Here (see Fig. 2), the general idea is to improve foreign languages skills (Cruz-Lara, 2011; Cruz-Lara et al., 2009).

Let's say that Pierre is a French student who has a good knowledge of English. However, his skills are not perfect yet and he wishes to talk in real time with native English-speaking people. That is why he connects to a virtual world, such as Second

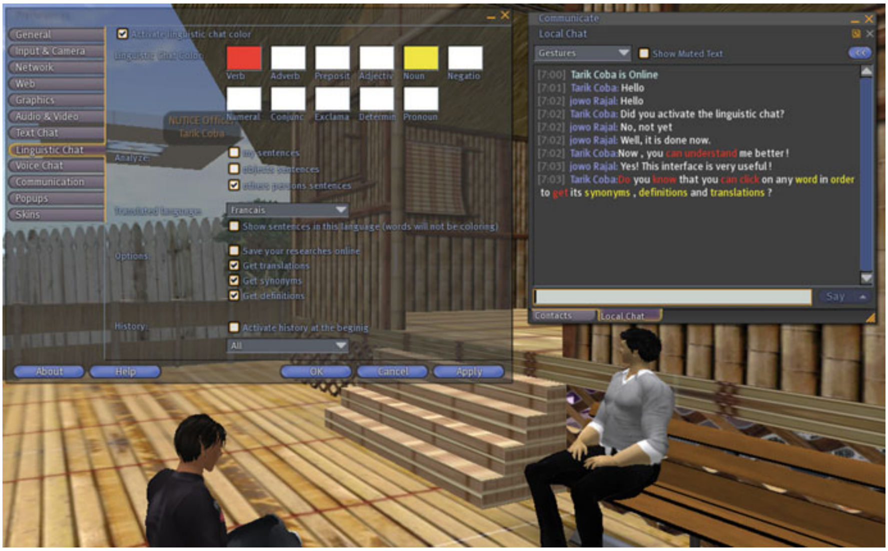



**Fig. 2** Different font colors for nouns and verbs displayed in the chat interface

Life, and teleports to one of the most popular virtual islands in the United Kingdom. He can now talk through the chat interface with native English-speaking people. The virtual world makes the situation less alarming than in the real world so that Pierre feels more comfortable during the talks. He does not feel as nervous as he usually is in real life, when talking in a foreign language. The virtual world also makes the chat based talk more immersive than the usual chat interfaces, as it offers the users a nice 3D environmental context.

Pierre is going to meet English people, and suggests that they watch a movie together in a virtual cinema. Pierre may display on his screen the subtitles in a selected language whereas his virtual friends do not need them. He can also talk about his impressions concerning the movie or about the cultural differences. In that case, the displayed subtitles are clickable.

But Pierre's English knowledge is still not good enough to understand everything he hears or reads and he still needs to click on some words in order to get synonyms, translations or definitions in real time. Sometimes, he also enables the syntax coloration, for example in order to highlight the verbs displayed in the chat window of his local user interface.

Every time Pierre clicks on a word, the system memorizes the searched information. Doing so, Pierre can afterwards deal with the words and expressions that were a bit difficult to him. In addition to that, he may not always have time to consult the information right away, and this functionality leaves Pierre more time to get focused on the talk in the virtual world. The sentences containing the searched words or expressions are also kept in memory, so that Pierre can replace his searches in the context and have a usage example for each word.

### 3.2 e-Language Learning

The INTERREG-III ALLEGRO project (Amoia, 2011; Amoia et al., 2011) aims at making language learning more challenging and entertaining. It attempts to differentiate itself from the regular serious gaming market by relaying extensively on Natural Language Processing (NLP) systems. The introduction of these technologies allows for very sophisticated language learning exercises, contrasting with previously developed products, based on keywords, template based generation, or a choice of fixed answers.

Thanks to language generation, the player can be confronted with many different ways to perform the very same exercise, increasing the players interest, lowering its ability to remember previous exercises answers, and adapting the difficulty to the players level; in short: it raises the challenge to another level.

This versatility enabled the use of dynamic environments, and this is why virtual universes were naturally chosen as a base for the game environment, allowing for a broader audience, easy maintenance, and cut on development costs in comparison with the costs of a dedicated 3D application (Bretaudière et al., 2011).

### 3.3 Conversation Support in Serious Games

Serious games engage players towards the acquisition of new skills rather than merely entertain them. Typically, they are designed for education, training or general counseling and assistance. Virtual Characters (VCs) or Embodied Conversational Agents (ECAs) can enrich users engagement through interactive conversations (Cassell et al., 1999). For instance, VCs can help players to achieve some goals inside the game, such as, orienting players to find some place in a 3D environment, or providing relevant information at each level of the game.

Cognitive models have been proposed for representing conversational agents beliefs, desires and intentions. The levels of thrust, credibility and cooperativeness have been subject of study in the last years, in which VCs can be collaborative or not (Roque & Traum, 2007). Our aim in the EUROSTAR EMO-SPEECH project (Bretaudière et al., 2011) is to provide virtual characters in serious games with conversation capabilities in collaborative environments.

In our first case study (see Fig. 3), we integrated this dialogue framework with the serious game "Mission Plastechnologie" (http://www.mission-plastechnologie.com) developed by Artefacto (http://www.artefacto.fr). In this game, the player has to manufacture a joystick in a Plastech Factory. The employees of the factory are very collaborative and help the player to manufacture it. They explain the production and recycling processes, the different jobs and the security measures. Several characters are engaged in 12 different dialogues during the game (the game and its dialogues are in French). Particularly, the roles of the player and the system are


**Fig. 3** Scenes of the game "Mission Plastechnologie"

interchanged during the game depending on the game level. Three possible characters can represent the player: Julie, Lucas, and Ben (see Fig. 3, right-hand side).

## *3.4 Sentiment Analysis and Emotion Detection*

### 3.4.1 Foreword

In this section we will introduce in a rather detailed way, two fields that represent our main ongoing research activities: sentiment analysis and emotion detection on textual information.

First, we consider that it is extremely important to define as rigorously as possible these two fields. That is the reason why a detailed presentation is given in this section. Second, once that sentiment analysis and emotion detection have been properly defined, we explain how they can be related to linguistic and multilingual issues, and then associated to virtual worlds and serious games.

The experience of the user may be conveyed by the textual content of his utterances. The earliest aspect that is investigated in literature is the sentiment expressed by a user through an opinion. That is, how he feels, or more specifically, how he feels about a certain topic. The most general task is to find whether a text conveys a positive, negative or neutral sentiment. This task is at hand when there is a need to determine the opinion conveyed by the texts produced by a user or a community of users: detecting hostile messages and flame wars (Spertus, 1997), determining whether movies are appreciated (Pang, Lee, & Vaithyanathan, 2002; Turney, 2002) and thereby trying to predict movie success (Mishne & Glance, 2006; Sadikov, Parameswaran, & Venetis, 2009), opinions about products (Hu & Liu, 2004) including predicting sales (Liu, Huang, An, & Yu, 2007), assessing citizens satisfaction of public policies (Kim & Hovy, 2006) and predicting election results from Twitter (Tumasjan, Sprenger, Sandner, & Welpe, 2010). Note that predicting an election result from Twitter is still a controversial topic (Metaxas et al., 2011).

### 3.4.2 Sentiment Analysis

The term sentiment in the expression "sentiment analysis" is a bit misleading. It refers to polarized elements in a text and not to the general meaning of sentiment as an emotion, which is closer to the topic of emotion detection. Moreover in the literature, opinion and sentiment are often used interchangeably, an opinion being a sentiment about something. Sentiment analysis is related to subjectivity analysis (that is whether a text expresses a subjective or objective point of view), however a sentiment is not necessarily expressed through a subjective assessment, and not all subjective assessments express a sentiment. Table 1 shows examples of objective and subjective sentences that can convey a sentiment or not. The sentence "This car is red" is a purely objective sentence without polarized information, while "This car is broken" is also an objective sentence but which contains a negative sentiment about the car. The sentence "I think that this car is red" is a subjective sentence expressing a belief but without polarization, while "I love this car" is also a subjective sentence but which conveys a positive sentiment.

The most complete definition of the sentiment analysis task is probably provided by (Liu, 2012) in which an opinion is defined as a quintuple (*e, a, s, h, t*) where *e* is the name of an entity, *a* an aspect of this entity, *s* is a sentiment about *a*, *h* is the opinion holder, and *t* is the time when an opinion is expressed by *h*. For instance in "Linux configurability is loved by geeks", the entity *e* would be Linux, the aspect *a* would be the configurability of Linux, the sentiment *s* would be positive, the holder of the opinion *h* would be geeks, and the time *t* would be the time of utterance, that is (Linux, configurability, positive, geeks, now). The sentiment analysis task is then to output for a given text or sentence the set of opinions that this text conveys.

### 3.4.3 Multilingual Sentiment Analysis

All the research works reviewed so far cover the sentiment analysis task for English, machine learning algorithms are trained on English corpora and lexicons are in English only. Most work in multilingual or cross-lingual sentiment analysis focus on subjectivity analysis that consists in determining whether a document or sentence is subjective or objective, but we assume that these approaches may be applied to polarity analysis as well. When performing sentiment analysis in another language several strategies are possible (Banea, Mihalcea, & Wiebe, 2011), sorted here from the best to the worst cases. The ideal case is when an annotated corpus is available in the target language, or if it is possible to build such corpus automatically, then classical supervised learning methods are possible. If not, automated translation can be used: from an annotated English corpus to the target language and then use the translated corpus to train a classifier (Banea, Mihalcea, Wiebe, & Hassan, 2008), or vice versa by translating the target corpus into English and running an existing classifier for English (Denecke, 2008; Kim & Hovy, 2006),

**Table 1** Examples of subjectivity and sentimental sentences

| | Without sentiment | With sentiment |
|---|---|---|
| Objective | This car is red | This car is broken |
| Subjective | I think that this car is red | I love this car |

this operation can also be performed with manually aligned corpora (Mihalcea, Banea, & Wiebe, 2007). Another approach is to build directly the lexicon for the target language, by lexicon-crawling and bootstrapping techniques. The last strategy is to translate instead the English lexicon to the target language and use the translated lexicon (Kim & Hovy, 2006; Mihalcea et al., 2007), however this method does not seem to yield the best accuracy. We refer the interested reader to (Banea et al., 2011; Banea, Mihalcea, & Wiebe, 2010; Liu, 2012) for a good overview of the topic.

### 3.4.4 Emotion Detection

The sentiment defined as a polarity is a worthwhile metrics of the user satisfaction, however in some domains, we might want to explore more fine-grained metrics. The topic of "emotion detection" goes deeper in the description of the user feelings. It consists in finding the emotions that are conveyed by a sentence or a document. It can be considered as a more specific and harder task than sentiment analysis: sentiment analysis is restricted to two or three classes (positive, negative, neutral) while emotion detection consists in finding emotions from a larger set of emotions and those are more complex than polarity. Typically, the set of emotions that is the most used is the Ekman's model (Ekman, 1972) that contains seven emotions (joy, sadness, fear, disgust, anger, surprise, interest), sometimes restricted to six, five or four emotions (joy, sadness, anger, fear). For instance the sentence "Trolley Square shooting leaves 6 dead, including gunman" could be said to convey a mixture of sadness, fear and anger.

It is interesting to compare the domain of application of emotion detection with regards to sentiment analysis. Emotion detection is mostly at hand in domains that really carry strong emotional content such as fairy tales (Alm, Roth, & Sproat, 2005), dream diaries (Frantova & Bergler, 2009), mood in blog posts (Mishne, 2005), news headlines (Strapparava & Mihalcea, 2007), interaction with virtual agents (Ochs, Sadek, & Pelachaud, 2012), suicide notes (Pestian et al., 2012), etc. Actually, in any domain where emotion detection is relevant, it is possible to carry a sentiment analysis task. However emotion detection is much more subtle and cannot be applied in all domains where sentiment analysis is relevant: the set of emotions needs to be chosen according to the domain. For instance, in the tutoring domain, Ekman's emotions do not seem to address correctly the experience of the student, it is unlikely that the student will feel anger or sadness per se. Kort, Reilly, and Picard (2001) propose instead to consider cognitive-affective states described by the valence of the experience and its relationship to the learning effects (constructive learning or un-learning). A similar claim is made in (Baker, D'Mello, Rodrigo, & Graesser, 2010; Calvo & D'Mello, 2010) in which cognitive-affective states like boredom or frustration are proposed. Interestingly these cognitive-affective states can be expressed in terms of valence/arousal, and then in this domain a sentiment analysis task would also be perfectly relevant.

To summarize, both sentiment analysis and emotion detection are interesting measures of the user experience. However emotion detection may not be relevant in all domains and it is moreover widely acknowledged to be a more complex task than sentiment analysis. On the contrary, sentiment analysis is a relatively easier task, which can be applied in most domains but only provides binary polarity information about the user experience.

### 3.4.5 Implementing Some Prototypes for Sentiment Analysis and Emotion Detection

In the framework of the ITEA3 Empathic Products project (ITEA3 11005; http://www.empathic.eu) we are currently developing several prototypes for sentiment analysis and emotion detection (see Fig. 4).

On the left-hand side, a gauge indicates a positive (i.e., green), negative (i.e., red), or neutral (i.e., orange) sentiment detected on a keyword (i.e., apple). The sentiment analysis is performed in real-time on Twitter. The number of tweets that have been analyzed is shown below the keyword (i.e., 21). On the right-hand side a similar prototype implements emotion detection. Once again, the detection is performed on a keyword (i.e., google), in real-time on Twitter. The "emotion display" shows by using icons and text, the emotions that have been detected and the percentage related to each of the detected emotions (i.e., joy, fear, anger, disgust, sadness, and surprise). The number of tweets that have been analyzed is shown in the middle of the display (i.e., 27).

Both prototypes (i.e., sentiment analysis and emotion detection) are based on natural language processing tools. Roughly, for emotion detection, the approach is similar to (Chaumartin, 2007), that is, we use an emotion lexicon, namely WordNet-Affect (Strapparava and Valitutti, 2004) (http://wndomains.fbk.eu/wnaffect.html). WordNet-Affect is an extension of WordNet Domains (http://wndomains.fbk.eu/) including a subset of synsets (i.e., set of synonyms) suitable to represent affective concepts correlated with affective words (Strapparava & Mihalcea, 2007). The sentence is analyzed with respect to several ordered filters (smileys, semantic rules, keywords) with a naive treatment of negation that inverts the found emotion. For sentiment analysis, we are currently exploring two opposed approaches, one symbolic and one with machine learning. The symbolic approach attempts to both tackle some linguistic difficulties (i.e., a word can have different polarities in different contexts) and domain dependence by using some general-purpose lexicons. The second approach relies on machine learning by training a classifier, namely a Random Forest classifier evaluated on the Semeval-13 dataset (SemEval, 2013).


**Fig. 4** Sentiment analysis and emotion detection on a mobile device

### 3.4.6 Associating Sentiment Analysis and Emotion Detection to Virtual Worlds

In the framework of the ITEA2 METAVERSE1 (ITEA2 07016) project we have associated emotion detection from textual information (i.e., chat-based dialogues) to the Solipsis (http://en.wikipedia.org/wiki/Solipsis) and Second Life virtual worlds.

The general scenario is the following: two avatars meet somewhere in Solipsis (or SecondLife) and start a discussion by using the chat tool. Roughly, we have used here the same approach as that of Fig. 4 (right-hand side). That is, each sentence in the chat is analyzed in real-time with respect to several ordered filters (smileys, semantic rules, keywords). Emotion detection is performed by using WordNet-Domains, WordNet-Affect, and a corpus containing several manually annotated phrases.

The Emotion detection architecture that has been implemented is shown in Fig. 5. Elements in orange color are internal and thus dependent of a particular virtual world (Solipsis or Second Life™ in the ITEA2 METAVERSE1 project); elements in blue color are independent from any virtual world and they are related to our emotion detection prototype; finally, elements in green color represent external tools that we use associated to the emotion detection prototype (WordNet-Domains, WordNet-Affect, and part-of-speech taggers).

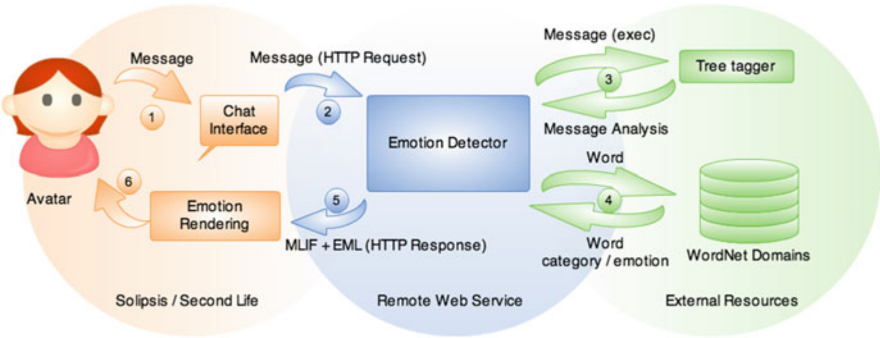



**Fig. 5** The emotion detection architecture in the ITEA2 METAVERSE1 project

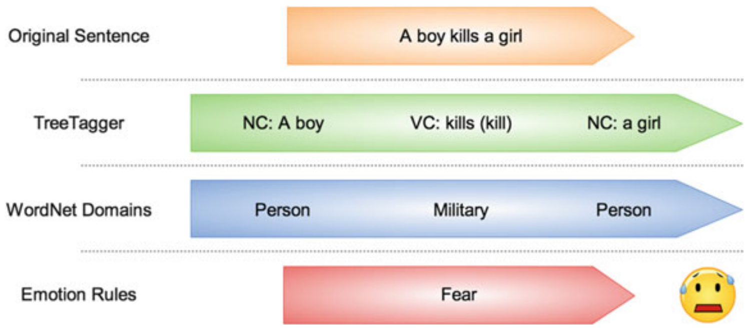


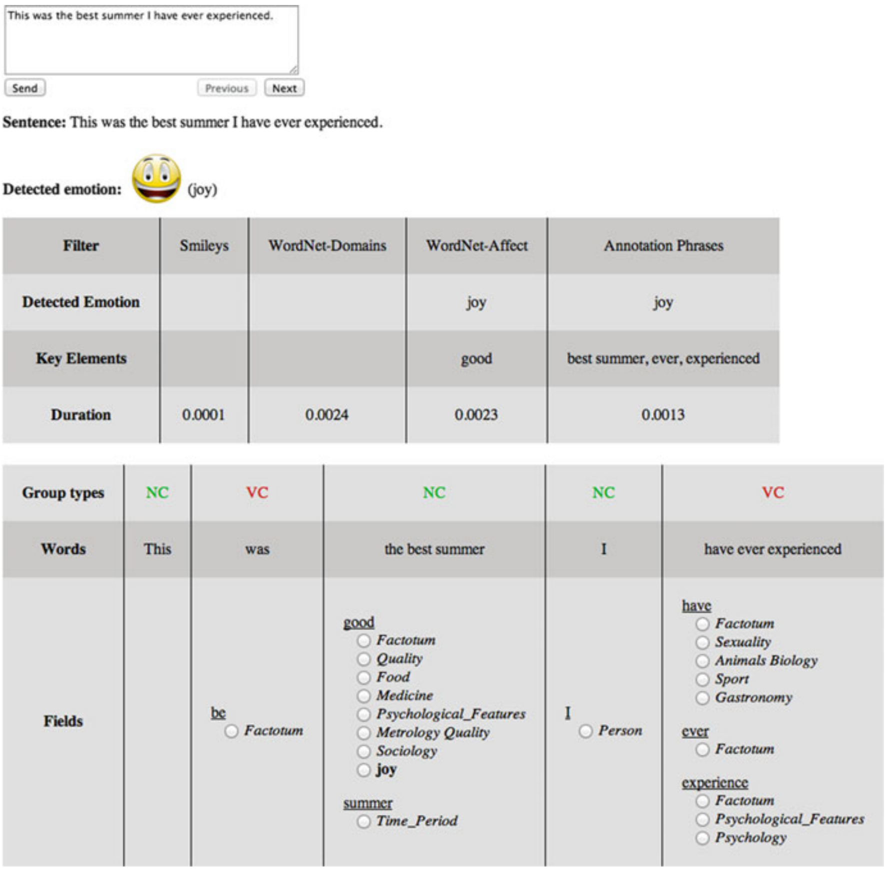

**Fig. 6** Detecting emotions in the ITEA2 METAVERSE1 project

There are six steps represented in Fig. 5:

1. A user, represented by un avatar, uses the chat tool in order to write a message;
2. The message is sent to the emotion detection prototype by using an http request;
3. The message is parsed and analyzed by the "tree tagger". Roughly, this tool identifies the syntactic categories of the elements in the sentence: verbs, nouns, adjectives, ... (http://www.cis.uni-muenchen.de/~schmid/tools/TreeTagger/)
4. A search is then performed in WordNet-Domains and WordNet-Affect in order to try to find an association between domains, synsets and emotions;
5. If an association is found, the detected emotion is encoded (see the Standardization section) by using MLIF and EmotionML standards (see Fig. 6);
6. Finally, the emotion rendering tool changes the face of the avatar according to the detected emotion. Figure 7 illustrates emotion detection in Solipsis.

Our emotion detection tool can also be directly accessed on the web (see Fig. 8): http://talc.loria.fr/~metaverse/web/emotions/filterDetection/corpusCreation.php


**Fig. 7** Emotion detection in Solipsis



This was the best summer I have ever experienced.

Send Previous Next

**Sentence:** This was the best summer I have ever experienced.

**Detected emotion:** (joy)

| Filter | Smileys | WordNet-Domains | WordNet-Affect | Annotation Phrases |
|---|---|---|---|---|
| **Detected Emotion** | | | joy | joy |
| **Key Elements** | | | good | best summer, ever, experienced |
| **Duration** | 0.0001 | 0.0024 | 0.0023 | 0.0013 |

| Group types | NC | VC | NC | NC | VC |
|---|---|---|---|---|---|
| **Words** | This | was | the best summer | I | have ever experienced |
| **Fields** | | be<br>○ *Factotum* | good<br>○ *Factotum*<br>○ *Quality*<br>○ *Food*<br>○ *Medicine*<br>○ *Psychological_Features*<br>○ *Metrology Quality*<br>○ *Sociology*<br>○ **joy**<br>summer<br>○ *Time_Period* | I<br>○ *Person* | have<br>○ *Factotum*<br>○ *Sexuality*<br>○ *Animals Biology*<br>○ *Sport*<br>○ *Gastronomy*<br>ever<br>○ *Factotum*<br>experience<br>○ *Factotum*<br>○ *Psychological_Features*<br>○ *Psychology* |

**Fig. 8** Our web-based emotion detection tool

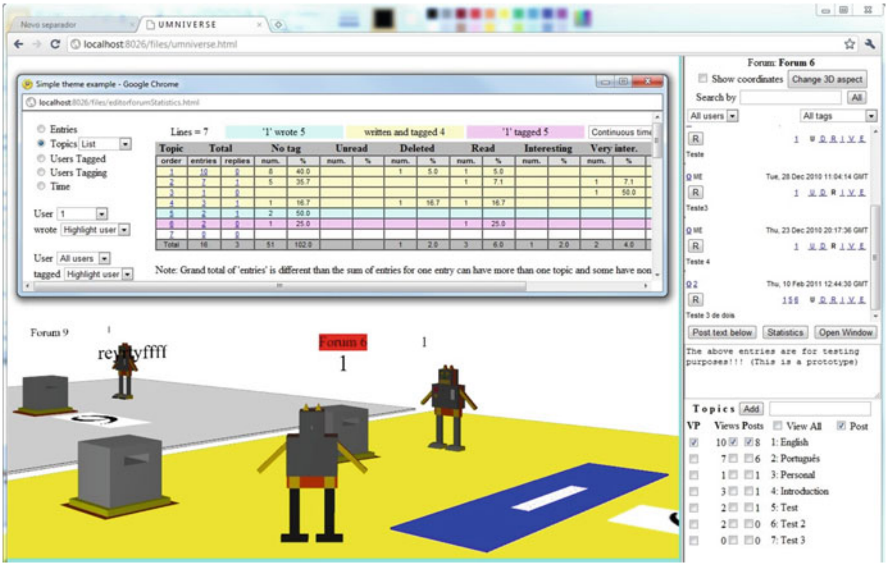



**Fig. 9** The Umniverse collaborative virtual world

### 3.4.7 e-Learning Virtual World Emotion Tagging

e-learning in a virtual world requires some level of investment by the participants and is eased by their collaboration. It has been shown that emotional information can enhance the collaboration. For instance (Kamada, Ambe, Hata, Yamada, & Fujimura, 2005) show that participants interact more if provided with emotional clues about their partner's current state. We propose to integrate our sentiment analysis tool to the Umniverse collaborative virtual world (Reis & Malheiro, 2011): the virtual world works as a situated forum in which participants can move around and submit posts (see Fig. 9). When participants submit posts they can annotate by hand the emotion that their post carries (with Ekman's emotions). Our tool can then be used to pre-annotate each post by proposing automatically an emotion.

After posts have been annotated and published to the forum, it is possible to filter the existing posts by their annotated emotion and as such find all the posts that carry sadness for example. Similarly to (Kamada et al., 2005) the assumption is that the participants will collaborate more or better if they can express their emotions and react to their peers' emotions as well.

## 4 Standardization

In order to enhance interoperability between virtual worlds, applications, and multilingual corpora, using standards is mandatory. That is the reason why we have spent lot of efforts in the specification of the "MultiLingual Information Framework" (MLIF) [ISO 24616:2012] (Cruz-Lara, 2011; Cruz-Lara et al., 2010).

In this section, we will briefly present the EmotionML standard, and we will explain how we are currently using it within the ITEA3 Empathic Products project (ITEA3 11005).

## 4.1 The EmotionML Standard (from W3C's Website)

The Emotion Markup Language (EmotionML) is a W3C candidate recommendation aiming to strike a balance between practical applicability and scientific well-foundedness. The language is conceived as a "plug-in" language suitable for use in three different areas: manual annotation of data, automatic recognition of emotion-related states from user behavior, and generation of emotion-related system behavior.

So, roughly, use cases for EmotionML can be grouped into three broad types: First, manual annotation of material involving emotionality, such as annotation of videos, of speech recordings, of faces, of texts, etc; second, automatic recognition of emotions from sensors, including physiological sensors, speech recordings, facial expressions, etc., as well as from multi-modal combinations of sensors; and third, generation of emotion-related system responses, which may involve reasoning about the emotional implications of events, emotional prosody in synthetic speech, facial expressions and gestures of embodied agents or robots, the choice of music and colors of lighting in a room, etc.

Concrete examples of existing technology that could apply EmotionML include: opinion mining/sentiment analysis in Web 2.0, to automatically track customer's attitude regarding a product across blogs; affective monitoring, such as ambient assisted living applications for the elderly, fear detection for surveillance purposes, or using wearable sensors to test customer satisfaction; character design and control for games and virtual worlds; social robots, such as guide robots engaging with visitors; expressive speech synthesis, generating synthetic speech with different emotions, such as happy or sad, friendly or apologetic; expressive synthetic speech would for example make more information available to blind and partially sighted people, and enrich their experience of the content; emotion recognition (e.g., for spotting angry customers in speech dialog systems); support for people with disabilities, such as educational programs for people with autism. EmotionML can be used to make the emotional intent of content explicit. This would enable people with learning disabilities (such as Asperger's Syndrome) to realize the emotional context of the content; EmotionML can be used for media transcripts and captions. Where emotions are marked up to help deaf or hearing-impaired people who cannot hear the soundtrack, more information is made available to enrich their experience of the content.

In April 2011, an XML Schema and a MIME-type for EmotionML were defined. The following example shows how automatically annotated data from three affective sensor devices might be stored or communicated:

*Example 1* Automatically annotated data from three affective sensor devices.

```
<emotionml xmlns="http://www.w3.org/2009/10/emotionml"
     category-set="http://www.w3.org/TR/emotion-voc/xml#everyday-
     categories">
...
<emotion start="1006526160000" expressed-through="face">
<!--the first modality detects excitement.
       It is a camera observing the face. A URI to the database
       is provided to access the video stream.-->
<category name="excited"/>
 <reference uri="http://www.example.com/facedb#t=26,98"/>
</emotion>

<emotion start="1006526160000" expressed-through="facial- skin-color">
 <!--the second modality detects anger. It is an IR camera
       observing the face. A URI to the database
       is provided to access the video stream.-->
  <category name="angry"/>
<reference uri="http://www.example.com/skindb#t=23,108"/>
</emotion>

<emotion start="1006526160000" expressed-through= "physiology">
  <!--the third modality detects excitement again. It is a
       wearable device monitoring physiological changes in the
       body. A URI to the database
       is provided to access the data stream.-->
  <category name="excited"/>
<reference uri="http://www.example.com/physiodb#t=19,101"/>
</emotion>

<emotion       start="1006526520000"       expressed-through=
$32#"physiology">
  <category name="angry"/>
   <reference uri="http://www.example.com/physiodb2#t=2,6"/>
</emotion>
...
</emotionml>
```

## 4.2 Using EmotionML in the ITEA3 Empathic Products Project (ITEA3 11005)

We are currently using EmotionML for sentiment analysis and emotion recognition. The general idea is to perform sentiment analysis and emotion recognition from the syntactic and semantic analysis of sentences from chat-based tools or social networks such as Twitter™.

In order to be able to use different kinds of resources, we defined a unified XML schema for representing both lexicons and corpora. This format allows representing linguistic information in relation to EmotionML. The lexical aspects of the schema model are represented by lexical items (i.e., lemmas and their part-of-speech). The corpora aspects of the schema represent a corpus as a collection of texts, which can be decomposed into lists of sentences. The sentences themselves can be annotated as sequences of inflected forms/lemmas pairs, including syntactic information such as the dependencies. Both sentences and texts can be annotated with one or several EmotionML emotions. The schema has been implemented in XSD, and is used in our Java API.

The following example (SemEval-07, http://nlp.cs.swarthmore.edu/semeval/) shows how annotated lexical data might be associated to Ekman's basic emotions:

*Example 2* Associating basic emotions to annotated lexical data.

```
<sentence id="1414">
        <content>Trolley Square shooting leaves 6 dead, including
        gunman</content>
        <tagged-content>
            <tagged-word pos="NN" lemma="trolley" morph="trolley"/>
            <tagged-word pos="NN" lemma="square" morph="Square"/>
            <tagged-word pos="NN" lemma="shooting" morph="shooting"/>
            <tagged-word pos="VBZ" lemma="leave" morph="leaves"/>
            <tagged-word pos="CD" lemma="6" morph="6"/>
            <tagged-word pos="JJ" lemma="dead" morph="dead"/>
            <tagged-word pos="," lemma="," morph=","/>
            <tagged-word pos="VBG" lemma="include" morph="including"/>
            <tagged-word pos="NN" lemma="gunman" morph="gunman"/>
        </tagged-content>
        <emotion>
            <info>
                <origin source="semeval-ekman" xml:lang=”en” />
            </info>
            <category confidence="1.0" value="0.87" name="sadness"/>
            <category confidence="1.0" value="0.18" name="surprise"/>
            <category confidence="1.0" value="0.0" name="joy"/>
            <category confidence="1.0" value="0.12" name="anger"/>
            <category confidence="1.0" value="0.0" name="disgust"/>
            <category confidence="1.0" value="0.57" name="fear"/>
        </emotion>
        <emotion>
            <info>
                <origin source="semeval" xml:lang=”en” />
            </info>
            <category confidence="1.0" value="0.0" name="valence"/>
        </emotion>
</sentence>
```

Remarks and comments about Example 2:

<sentence> represents the sentence that has been analyzed;

<content> represents the sentence as a string;

<tagged-content> contains the elements in the sentence. The meaning of attributes is the following:

pos: part-of-speech morphological tags. Morphological tags represent different kinds of words such as: verbs, nouns, adjectives, etc.
lemma: the canonical form of a word;
morph: a word.

<emotion> an EmotionML element allowing to associate emotions to sentences. This element is fully based on EmotionML.

In the framework of sentiment analysis, we will also use Emotion-ML. The following example shows how annotated lexical data might be associated to positive, negative, or neutral sentiments:

*Example 3* Associating positive, negative, or neutral sentiments to annotated lexical data.

```
sentence id="266290644207681536">
<content>@bryony_q Omg really totes loving this.. :) xxx</content>
<emotion>
<info>
<origin source="twitter" xml:lang="en" />
</info>
<category confidence="1.0" value="1.0" name="valence"/>
</emotion>
</sentence>
<sentence id="266460172858310656">
<content>Major migrane going on now :( q</content>
<emotion>
<info>
<origin source="twitter" xml:lang="en" />
</info>
<category confidence="1.0" value="0.0" name="valence"/>
</emotion>
</sentence>
```

Remarks and comments about Example 3:
<sentence> represents the sentence that has been analyzed;
<content> represents the sentence as a string;
<emotion> an EmotionML element allowing to associate sentiments to sentences;

Within the <category> element, the "value" attribute means: 0.0 is a fully negative sentiment, 1.0 is a fully positive sentiment, and 0.5 is a neutral sentiment.

## *4.3 Emotion Annotation*

We first defined a Java interface EmotionAnnotator for annotating emotions for texts or sentences. In order to do several experiments on sentiment analysis, we implemented this interface in several ways. We first integrated the annotator that we have developed for the ITEA2 METAVERSE1 project. We then tried several other approaches, first at the lexical level (using only lexicon words valence) and at the syntactic level (using also valence shifting rules). The lexical level requires the use of a tagger, a tool that produces the lemmas from the inflected forms found in the text. As for the syntactic level, it requires the use of a parser to produce the syntactic dependencies between lemmas. For both purposes we based our work on the Stanford Core NLP (http://nlp.stanford.edu/software/corenlp.shtml) a high quality library that both contains taggers and parsers. Next we tried statistical sentiment analysis thanks to the WEKA library (data mining software in Java, http://www.cs.waikato.ac.nz/ml/weka/), after importing our data within the WEKA format, we experimented several supervised machine-learning algorithms. However, the two kinds of approaches have their own advantages and deficiencies. While the lexical/syntactic annotators, including the annotator of the ITEA2 METAVERSE1 project, are relatively domain independent and perform well for simple sentences not too complex, they fail at capturing the diversity of valence phenomena and thus obtain low accuracy on our evaluation corpus (the Sanders corpus around 3300 annotated tweets with valence; http://www.sananalytics.com/lab/twitter-sentiment/). On the contrary, the statistical annotators manage to obtain fair accuracy on the Sanders corpus, but fail to be domain independent and thus tend to have wrong results on small generic sentences. The next objective is to see if it is possible to combine both kinds of annotators, either in a sequential way, or by learning domain independent valence shifting rules from our corpora.

## 4.4 Our Contribution to EmotionML

W3C's Multimodal Interaction Working Group who has published EmotionML as a W3C's Recommendation on May 22nd, 2014 has officially referenced our work within its Multimodal Interaction Activity webpage.

(http://www.w3.org/2002/mmi/implementations.html#emotionml).

## 4.5 The SATI API

The SATI API (http://talc2.loria.fr/empathic) enables to perform Sentiment Analysis from Textual Information. It is accessed through HTTP GET requests. The format of requests is: http://talc2.loria.fr/empathic?QUERY, where QUERY is formatted as parameter/value pairs separated by the & character.

For instance http://talc2.loria.fr/empathic?text=I+love+apples&engine=metaverse will perform the analysis of the sentence "I love apples" using the emotion detection prototype of the ITEA2 METAVERSE1 project, and return the value "joy". Figure 10 illustrates the multilingual part of the SATI API, while Fig. 11 shows all available parameters.

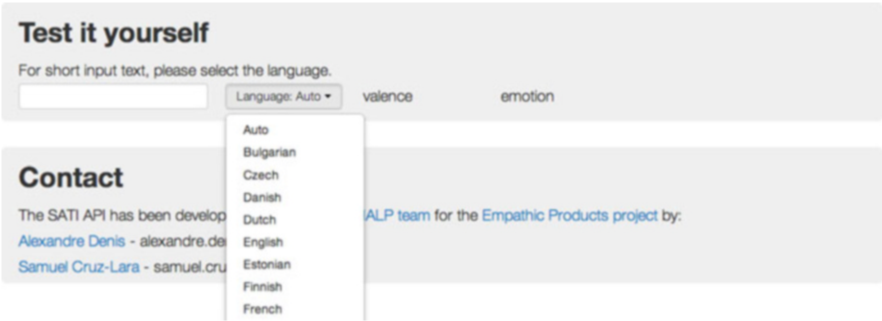



**Fig. 10** Multilinguality in the SATI API

It must be noted that multilingual sentiment analysis is actually performed in English (cf. Multilingual sentiment analysis). All required translations, as well as language detection, are accomplished by using the Google Translate API.

## 5 Visualization of Affect in Movie Scripts

Affective based movie search is relatively recent. One of the most prominent works is the iFelt system (Oliveira, Martins, & Chambel, 2013) that proposes to search for movies according both to the emotions em- bedded in the movie (or objective emotions in the authors' terminology) and to the emotions elicited in the viewer (or subjective emotions). The iFelt system classifies subjective Ekman emotions thanks to physiological inputs (ECG, blood pressure, etc.) and considers audio/video/subtitles analysis. Once classified the system enables to search for a movie using a visual representation of all movies according to their emotions. Another system is the BBC classification system (Eggink & Bland, 2012) that targets objective emotions using TV specific dimensions such as happy/sad, light-hearted/dark, serious/humorous or fast-paced/slow-paced. They observed that the serious/humorous and the fast/slow pace were the two most important dimensions. Their classifier obtains very good accuracy for these two dimensions using audio/video signal processing, including genre information.

It is noteworthy to remark that none of these works consider movie scripts. However movie scripts are a rich source of information: they are split by scenes, attribute dialogues to characters, provide scene descriptions and stage directions. All these aspects that are not present in subtitles could be used to discover the affect contained in a movie.

We first downloaded around 1150 movie scripts in flat text from IMSDB.com, the Internet Movie Scripts Database. We then filtered out all scripts that prevented to extract scenic information (because of non machine readable format, scripts with erroneous characters, etc.). We kept then around 750 movie scripts to work with.

## Parameters

### text

**name** text
**description** the text parameter specifies the input text that is to be analyzed. The text value needs to be formatted using the URL encoding. See also RFC 3986 . The text value is preferrably in English. We provide analysis in other languages than English, the input language being automatically detected by default. Note that if the text parameter is missing, the engine returns a default emotion.
**type** string

### lang

**name** lang
**description** the lang parameter specifies the input text language as standardized by the ISO 639-1. It accepts the default value "auto" to automatically detect the input language. The success of automatic language detection depends on the length of the input text. For short input texts, it is advised to specify the lang parameter.
**type** string
**default** auto

### engine

**name** engine
**description** the engine parameter specifies which sentiment analysis engine will be used for sentiment analysis. Different engines may have different kinds of outputs. See the EmotionML vocabulary document for getting the types of vocabulary used byeach engine.
**type** string
**values** syntactic_liu_urban,syntactic_mpqa,metaverse
**default** syntactic_liu_urban

### output

**name** output
**description** the output parameter specifies how the output will be formatted. The "value" output is the simplest format: for engines that return valence information it returns a real value between 0 and 1, 1 being positive, 0 negative and 0.5 neutral. For engines that return emotion information it returns a value defined in a set of values that depends on the engine, for instance the metaverse engine returns a value in {joy, sadness, fear, disgust, ...}. The "xml" output corresponds to a XML representation of the emotion in the EmotionML format. The "json" output corresponds to the same content than the XML representation but formatted using JSON.
**type** string
**values** value,xml,json
**default** value

### query

**name** query
**description** the query parameter specifies the function of the api that is to be called. The "analysis" query corresponds to the main function that analyzes text. The "info" query returns information about the api formatted in XML. The "vocabularies" query returns the vocabularies used by the engines in EmotionML format.
**type** string
**values** analysis,info,vocabularies
**default** analysis

### twitter

**name** twitter
**description** the twitter parameter enables to perform the analysis of tweets that contain the given text. If true, it returns the sentiment analysis of the first found tweet containing the text as provided with the text parameter. Since this query waits for a tweet to be published in real time, it is better to call it asychronously with AJAX requests.
**type** boolean
**default** false

**Fig. 11** Available parameters of the SATI API

These scripts were then parsed and better formatted. Most of these scripts were very close to the Fountain format, a plain text format for screen writers that clearly delineates the dialogue lines from the scene descriptions. For the rest of the scripts, regular expressions were used. Eventually four types of information are an- notated: the scene headings (interior/exterior, time of day, location); the scene descriptions, the description of the locations, actions and behaviors of the characters; the dialogue lines, that is what the characters say; and the stage directions which provides additional information regarding the attitudes or actions of characters while they speak. We will refer to these elements as script elements. The appendix shows an example of formatted script.

The affect analysis of the movie script content has been performed thanks to SATI API that enables to retrieve the sentiment (a continuous value in [0, 1]) and the emotion (Ekman emotions) that is conveyed by a text. Both analyses use symbolic approach since classical supervised learning tends to be domain dependent. Both approaches are based on lexicons (Liu's lexicon for polarity and Wordnet-Affect for emotions). In order to deal with negation or valence shifts caused by adjectives (see for instance the expression "it is a missed opportunity"), the sentiment analyzer makes use of parsing techniques: it first parses the sentence using Stanford parser, associates each word with its polarity from the lexicon and applies valence modification rules iteratively until no more rule can be applied. Each of the four elements (scene headings, descriptions, dialogue and directions) were annotated both with the valence and an Ekman emotion. The final result has been formatted in the EmotionML format as a standalone EmotionML document whose emotions are referred to thanks to an emoId.

## *5.1 Affect Visualization*

We are interested here in visualizing the affect of the 750 annotated movie scripts and propose something similar to iFelt with its movie space. Valence information is the easiest to display. Figure 1 shows an example on how to display movies by valence: all movies are represented as dots, the distance from the center and the color giving information on the average valence of the movie including all script elements (red meaning negative, green positive). The user can hover a particular dot and see information about the movie. The figure shows both the poster of the movie that the user hovered and the timeline information, showing average valence for each scene. Hovering the timeline enables to see the actual content of the scene in terms of descriptions or dialogue elements along with their corresponding valence (Fig. 12).

Emotions visualization is a bit trickier. Figure 13 shows emotions laid out following Plutchik (Plutchik, 2001) wheel style of visualization. Given a movie, its emotional profile is simply computed by counting all occurrences of Ekman

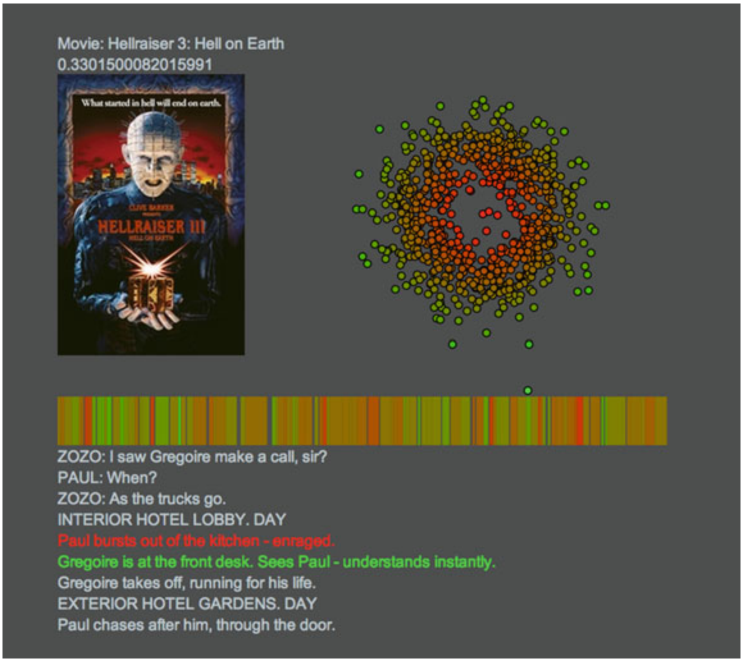



**Fig. 12** Valence visualization for all movies and by timeline

emotions in script elements and calculating the ratio of each emotion, for instance (joy = 0.5, fear = 0.1, sadness = 0.2, disgust = 0.0, surprise = 0.1, anger = 0.1). The movies are then displayed as dots such that, the higher each emotion, the closer they are to the corresponding corners. Like for valence, the user can hover each dot and have information about the movie. Here the information is the emotional distribution of all characters of the movie. We consider in this figure the emotional analysis of the dialogue lines of the characters. Another visualization could consider the scene descriptions involving the characters as well.

While the emotion visualization seems pleasant and readable, it is also inherently ambiguous since it is a two dimensional projection of the six dimensions emotional vector. The solution of iFelt is to be less informative and only display the most dominant emotion of the movie. Another solution, as used by the BBC system would be to perform a Principal Component Analysis to retrieve only relevant dimensions at the possible cost of readability.

Our preliminary work has been published in Empatex 2014 Workshop (Denis, Cruz-Lara, Bellalem, & Bellalem, 2014). Since this work is preliminary no evaluation has been conducted yet.

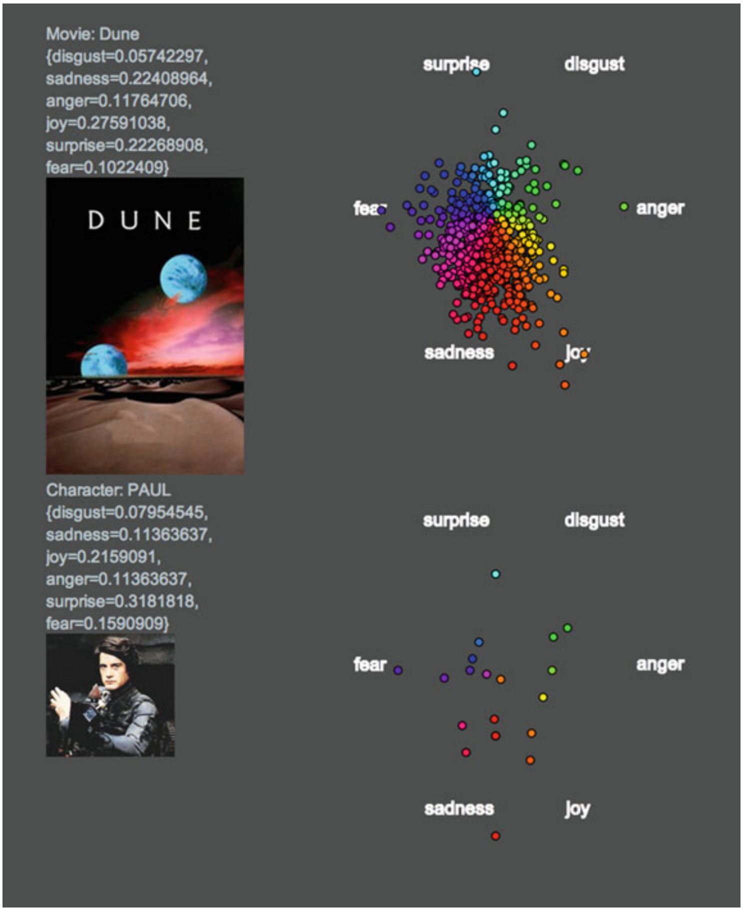



**Fig. 13** Emotion visualization for all movies and by characters

## 6 Dynamic Simulation of Emotions in a Video Game

We will describe here the latest activities related to our research work within the ITEA3 Empathic Products project (ITEA3 11005). It should be noted that we are only at the very beginning of our work that is related to the dynamic simulation of emotions in a video game. So, we indicate here some ideas that we think would be interesting:

- Detecting vs modeling emotions: in the ITEA Empathic Products project (ITEA3 11005), we mainly targeted emotions detection, but it is indeed interesting to consider why emotions do happen, that is what are the conditions in which an emotion is triggered. An emotion model has both a theoretical and a practical interest: if we can model the eliciting situations, we can influence the

resulting emotions by altering these situations, for instance avoid negative emotions and provoking positive emotions, or the opposite.
- User vs character: in the project we only considered the user's emotions. However, many of our emotions are targeted towards other agents and we react as well to other agents' emotions. It is therefore interesting to look at virtual agents, such as video game characters, both as the targets for user emotions and as emotions inducers. Additionally, including virtual characters enables to encompass a broader scope of more intense emotions: think for instance of the true sadness the player may feel when a loved character dies.
- Emotions as gameplay: in almost no existing game, emotions have been considered as part of the gameplay. At most they are superficial, only expressive, but never the player has been allowed to directly act upon emotions. The idea here is to use emotions as part of the game mechanics, for instance by restricting the player to act only upon the characters' emotions. It is a challenge since we should consider how these mechanics could interfere with the narrative.

A video game offers a natural dynamic setting to explore the emotions modeling in virtual characters. We can see two main tracks to concretize our ongoing work:

- Emotion modeling: a module that maintains an affective state per character and, given a situation and the character at hand, determines how to alter his/her affective state. It requires a logical model of the game situations, and some thinking about the relationships between emotions, personalities and actions.
- Game development: which consists in defining and developing a game in which the player can interact with the environment and the characters to alter their affective state. It involves game design, scenarios, graphics and audio settings, including coding as well. The game does not have to be huge in terms of content as long as it enables to exhibit dynamic emotional interactions.

## *6.1 Genre, Narrative and Emotions*

There are several possible video game genres to implement the idea of a dynamic emotion model. The main constraints are related to the characters and as such the genre needs to consider:

- Character interaction: whether the genre tends to display characters with which it is possible to interact, the more flexible the interactions the better (is that possible to do any actions character, marry them, kill them, etc. or is the set of actions restricted?).
- Character dynamics: whether the characters, if present, are modeled dynamically rather than statically, the more dynamic the better (are the characters reactive to the various environment they can be in or are they preconfigured to react in one single way?).

- Emotions: whether the genre is suited for emotions, whether the characters can display emotions and react to others emotions (do the characters exhibit custom and personalized emotions or are they interchangeable emotionless placeholders?).

We listed here genre suitability with some representative examples (in 1-5 scales) this is very subjective though:

| Genre | Interaction | Dynamics | Emotion | Total |
|---|---|---|---|---|
| Adventure (monkey island) | 3 | 1 | 5 | 9 |
| Role playing game (fallout) | 4 | 3 | 4 | 11 |
| Strategy (civilization) | 2 | 4 | 3 | 9 |
| Simulation (the sims) | 5 | 5 | 2 | 12 |

Nevertheless, the RPG and/or the simulation genres seem more suited than other genres. The main difficulty of adventure genre is the lack of dynamics, whereas the main difficulty of the strategy genre is low interaction and emotion levels. The role playing game seems adequate but dynamics seems more present for the simulation genre. The main problem of simulations is the lack of emotions that are very present in the adventure genre.

### 6.1.1 Starting from an Adventure Game (Guided by Plot)

If we would start from an adventure game, the narrative would be central whereas the gameplay dynamics would only be secondary. This is typically the case in the games like The Walking Dead, which could be described as an interactive narrative. The story is told like in a movie, with interactive cinematic, and there are few moments where the player can explore the environment and decide to whom he will speak (or with which objects to interact). There is a limited amount of branching.

A natural inclusion of emotions would be to have emotional characters in the story. For instance a given character may have important information for the investigation but may be sad because of the death of someone else, and soothing him/her can be part of the scenario to retrieve information and progress in the story. However, the dynamics would be very limited and actually constrained by the scenario: this particular character could not be angry unless we specify it in the scenario. As such, each possible emotion would imply different game states that we have to specify. Thus, embedding dynamic emotions inside the scenario entails a very important amount of work, even more if we want to consider relational emotions.

### 6.1.2 Starting from a Simulation (Guided by Character)

Actually the simulation may be easier to start with: the characters have their own mechanics describing how they would react to which events. The emotional aspect would be a further characterization of their behavior. The main problem of simulations is their lack of narrative. It is however possible to add a narrative level over simulations through an event-based mechanism. At some point of the simulation an event happens and the characters need to react to it. The idea to embed narrative-based emotions is that these events have an emotional charge. For instance one character (randomly) may die, and then other characters must react to his/her death. There is not much plot per se but rather a series of events. It is possible to add a level of mystery though typically the events may be related to some mystery that is unveiled throughout the simulation. The gameplay would then be to deal with characters emotions.

It raises the question though of the interplay between emotional characters and gameplay. If one considers the negative emotions as gameplay obstacles, then the characters that bear them will be unlikable and be considered as opponents. The risk is to have a general rejection of the game because the characters are not supportive and just annoying. One way to avoid this problem is such that the player shares the negative emotions experienced by characters. Then it is by sympathy that the player will be dealing with emotions.

Therefore the simulation needs to be constructed with two "affective acts":

1. Act 1. Emotional bonding: the player gets to know the characters, so he should sympathize with them. He should discover their quirks (see Bates, 1994, The Role of Emotion in Believable Agents) and really like them. Not all of them should necessarily be likable, maybe one of them will just be annoying to emphasize the contrast but the others need to be really likable: funny, friendly, positive, generous, honest, empathic, reliable, open, non judgmental, vulnerable... We could have stereotypes, for instance:

   - A funny, friendly, extravert one (but vulnerable).
   - An honest frank one (direct but fair).
   - An open wise one.
   - A deep mysterious introvert one.
   - A selfish intolerant one (the unlikable one).
   - ...

2. Act 2. Emotional chaos: now that we established that the player liked the characters, we should make the characters experience negative emotions such that the player sympathizes for the characters and almost feels the same emotions. The player motive is thus not outside the scenario but within his own feelings: he should really want to help the characters. The relational conflicts will be even more interesting if the player likes both characters: he may then have to pick a side.

## *6.2 The Global Scenario*

We are in 3014 on an exploratory spaceship. One day, the spaceship is strangely attracted into an asteroid field. While it enters the asteroid field, weird things start to happen: electro-magnetic and psychic perturbations that both threaten the physical integrity of the ship and the mental stability of the crew. You are the captain, an "empath", able to feel the emotions of your crew. Your goal is to deal with your crew stress and manage to exit the asteroid field: if their mental breaks down, the whole ship breaks down.

What the player doesn't know at first is that the asteroid field is actually an alien nursery: the asteroids are alien eggs that induce the physico-mental perturbations. Depending on the depth of what we can do, aliens may hatch and attack the ship. The mother alien may not be far either…

### *6.3 Remarks*

As we said at the beginning of this section, we're only at the very beginning of our work. Once again, what we are looking for is to consider why emotions do happen, that is what are the conditions in which an emotion is triggered.

## 7 Conclusion

We have presented a general review related to the association of linguistic and multilingual issues to 3D3C worlds. Beyond the "classical multilingual support" such as localization and automatic translation, we have shown that several non-intrusive and interactive tools such as a linguistic enhanced chat, as well as several natural language processing-based activities, such as e-learning—and in particular language learning-, conversation support, sentiment analysis and emotion detection, may be successfully associated to virtual worlds and serious games.

Sentiment analysis and emotion detection have been extensively explored, and we think that we have clearly exposed how they can be associated to linguistic and multilingual issues in order to improve the user experience in 3D3C worlds.

Our research work, particularly, in the framework of representing and managing multilingual textual information has contributed to the development of an ISO international standard the "Multi-Lingual Information Framework" (MLIF) [ISO 24616:2012] (Cruz-Lara, 2011; Cruz-Lara et al., 2010), but globally, our research work mainly contributes to the successful and innovative association of standardized linguistic-related tools to 3D3C worlds. As we have also shown in this paper, other a priori non linguistic-related standards such as EmotionML, can also be successfully used in this interesting association. Using standards is mandatory because they grant interoperability, stability, and durability. We have, in addition, shown that EmotionML's designers at W3C have officially taken our work into account.

We have also presented our latest research activities in the framework of a preliminary approach to visualize the affect carried by movies through the affective analysis of their scripts, and we have also cited our ongoing research work related to the exploration of a dynamic simulation of emotions in a video game: as we have clearly said, what we are looking for here is to consider what are the conditions in which an emotion is triggered. We think that if we can model the eliciting situations, we can influence the resulting emotions by altering these situations, for instance avoid negative emotions and provoking positive emotions, or the opposite.

## References


Alm, C., Roth, D., & Sproat, R. (2005). Emotions from text: Machine learning for text-based emotion prediction. In *Proceedings of human language technologies conference/conference on empirical methods in natural language processing (HLT/EMNLP 2005)*, Vancouver, Canada.

Amoia, M. (2011). I-FLEG: A 3D-game for learning French. In *Proceedings of the 9th international conference on education and information systems, technologies and applications (EISTA 2011)*, Orlando, FL, USA.

Amoia, M., Gardent, C., & Perez-Beltrachini, L. (2011). A serious game for second language acquisition. In *Proceedings of the third international conference on computer aided education (CSEDU 2011)*, Noordwijkerout, The Netherlands.

Baker, R., D'Mello, S., Rodrigo, M. M., & Graesser, A. C. (2010). Better to be frustrated than bored: The incidence, persistence, and impact of learner's cognitive-affective states during interactions with three different computer-based learning environments. *International Journal of Human-Computer Studies, 68*(4), 223–241.

Banea, C., Mihalcea, R., Wiebe, J., & Hassan, S. (2008). Multilingual subjectivity analysis using machine translation. In *Proceedings of the conference on empirical methods in natural language processing (EMNLP-2008).*

Banea, C., Mihalcea, R., & Wiebe, J. (2010). Multilingual subjectivity: Are more languages better? In *Proceedings of the 23rd international conference on computational linguistics (COLING-2010).*

Banea, C., Mihalcea, R., & Wiebe, J. (2011). Multilingual sentiment and subjectivity analysis. In I. Zitouni & D. Bikel (Eds.), *Multilingual natural language processing* (pp. 259–277). Upper Saddle River, NJ: Prentice Hall.

Bretaudière, T., Cruz-Lara, S., & Rojas Barahona, L. (2011). Associating automatic natural language processing to serious games and virtual worlds. *The Journal of Virtual Worlds Research*, *4*(3).

Calvo, R. A., & D'Mello, S. (2010). Affect detection: An interdisciplinary review of models, methods, and their applications. *IEEE Transactions on Affective Computing, 1*(1), 18–37.

Cassell, J., Bickmore, T., Billinghurst, M., Campbell, L., Chang, K., & Vilhjálmsson, H., et al. (1999). Embodiment in conversational interfaces: Rea. In *ACM CHI 99 conference proceedings*, Pittsburgh, PA.

Chaumartin, F. R. (2007). UPAR7: A knowledge-based system for headline sentiment tagging. In *Proceedings of the 4th international workshop on semantic evaluations (SemEval 2007)* (pp. 422–425).

Cruz-Lara, S. (2011). Mundos virtuales: Una infraestructura global para facilitar las interacciones sociales multilingües y el aprendizaje de idiomas. In *Proceedings of the VII International Conference on Engineering and Computer Education. Workshop "New Trends in Engineering Education"* (pp. 55–59), Guimarães, Portugal.

Cruz-Lara, S., Bellalem, N., Bellalem, L., & Osswald, T. (2009). Immersive 3D environments and multilinguality: Some non-intrusive and dynamic e-learning-oriented scenarios based on textual information. *The Journal of Virtual Worlds Research*, *2*(3).

Cruz-Lara, S., Francopoulo, G, Romary, L., & Semar, N. (2010). MLIF: A metamodel to represent and exchange multilingual textual information. In *Proceedings of the Language Resources and Evaluation Conference (LREC)*, Valletta, Malta.

Cruz-Lara, S., Osswald, T., Guinaud, J., Bellalem, N., & Bellalem, L. (2011). A Chat interface using standards for communication and e-learning in virtual worlds. *Lecture Notes in Business Information Processing, 73*(6), 541–554.

Denecke, K. (2008). Using SentiWordNet for multilingual sentiment analysis. In *Proceedings of the IEEE 24th International Conference on Data Engineering Workshop (ICDEW 2008).*

Denis, A., Cruz-Lara S., Bellalem, N., & Bellalem L. (2014, June 25). Visualization of affect in movie scripts. In *Proceedings of the 1st international workshop on empathic television experiences*, Newcastle-upon-Tyne, UK.

Eggink, J., & Bland, D. (2012). A large scale experiment for mood-based classification of tv programmes. In *Proceedings of the IEEE international conference on multimedia and expo* (pp. 140–145).

Ekman, P. (1972). Universals and cultural differences in facial expressions of emotions. In J. Cole (Ed.), *Nebraska symposium on motivation, 1971* (pp. 207–283). Lincoln, NE: University of Nebraska Press.

Frantova, E., & Bergler, S. (2009). Automatic emotion annotation of dream diaries. In *Proceedings of the analyzing social media to represent collective knowledge workshop at K-CAP 2009, The fifth international conference on knowledge capture*.

Hu, M., & Liu, B. (2004). Mining opinion features in customer reviews. In *Proceedings of AAAI 2004* (pp. 755–760).

Kamada, M., Ambe, M., Hata, K., Yamada, E., & Fujimura, Y. (2005). The effect of the emotion-related channel in 3D virtual communication environments. *Psychology Journal, 3*(3), 312–327.

Kim, S. & Hovy, E. (2006). Identifying and analyzing judgment opinions. In *Proceedings of the Human Language Technology/North American Association of Computational Linguistics conference (HLT-NAACL 2006)*, New York, NY.

Kort, B., Reilly, R., & Picard, R. W. (2001, August 6–8). An affective model of interplay between emotions and learning: Reengineering educational pedagogy-building a learning companion. In *Proceedings of the IEEE international conference on advanced learning technologies*, Madison, USA.

Liu, B. (2012, May). Sentiment analysis and opinion mining. In G. Hirst (Series Ed.), *Synthesis lectures on human language technologies*. San Rafael, CA: Morgan and Claypool Publishers.

Liu, Y., Huang, X., An, A., & Yu, X. (2007). ARSA: A sentiment-aware model for predicting sales performance using blogs. In *Proceedings of ACM SIGIR, 2007.*

Metaxas, P. T., Mustafaraj, E., & Gayo-Avello, D. (2011). How (not) to predict elections. In *Proceedings of Privacy, Security, Risk and Trust (PASSAT), 2011 IEEE Third International Conference on Social Computing (socialcom).*

Mihalcea, R., Banea, C., & Wiebe, J. (2007, June). Learning multilingual subjective language via cross-lingual projections. In *Proceedings of the 45th annual meeting of the association of computational linguistics*, Prague, Czech Republic.

Mishne, G. (2005). Experiments with mood classification in blog posts. In *Proceedings of the first workshop on stylistic analysis of text for information access*.

Mishne, G., & Glance, N. (2006). Predicting movie sales from blogger sentiment. In *Proceedings of AAAI 2006 Spring Symposium on Computational Approaches to Analysing Weblogs (AAAI-CAAW 2006).*

Ochs, M., Sadek, D., & Pelachaud, C. (2012). A formal model of emotions for an empathic rational dialog agent. *Autonomous Agents and Multi-Agent Systems, 24*(3), 410–440.

Oliveira, E., Martins, P., & Chambel, T. (2013). Accessing movies based on emotional impact. *Multimedia Systems, 19*(6), 559–576.

Pang, B., Lee, L., & Vaithyanathan, S. (2002). Thumbs up? Sentiment classification using machine learning techniques. In *Proceedings of EMNLP-02* (pp. 79–86).

Pestian, J. P., Matykiewicz, P., Linn-Gust, M., South, B., Uzuner, O., Wiebe, J., et al. (2012). Sentiment analysis of suicide notes: A shared task. *Biomedical Informatics Insights, 5*(Suppl. 1), 3–16.

Plutchik, R. (2001). The nature of emotions. *American Scientist*, *89*(4).

Reis, F., & Malheiro, R. (2011, May). Umniversity virtual world platform for massive open online courses University platform. In *IE challenges 2011 VII international conference on ICT in education*, Braga, Portugal.

Roque, A., & Traum, D. R. (2007). A model of compliance and emotion for potentially adversarial dialogue agents. In *Proceedings of the 8th SIGdial workshop on discourse and dialogue*.

Sadikov, E., Parameswaran, A., & Venetis, P. (2009, May 17–20). Blogs as predictors of movie success. In *Proceedings of the third international AAAI conference on weblogs and social media (poster papers)*, San Jose Mc Enery Convention Center, USA.

SemEval (2013, June 14–15). SemEval-2013: Semantic evaluation exercises. In *International workshop on semantic evaluation*, Atlanta, USA.

Spertus, E. (1997). Smokey: Automatic recognition of hostile messages. In *Proceedings of the conference on innovative applications of artificial intelligence* (pp. 1058–1065). Menlo Park, CA: AAAI Press.

Strapparava, C., & Valitutti, A. (2004, May). WordNet-Affect: An affective extension of WordNet. In *Proceedings of the Language Resources and Evaluation Conference (LREC 2004), Lisbon* (pp. 1083–1086).

Strapparava, C., & Mihalcea, R. (2007, June). SemEval-2007 Task 14: Affective text. In *Proceedings of the 4th International Workshop on the Semantic Evaluations (SemEval 2007)*, Prague, Czech Republic.

Tumasjan, A., Sprenger, T. O., Sandner, Ph. G., & Welpe, I. M. (2010, May 23–26). Predicting elections with twitter: What 140 characters reveal about political sentiment. In *Proceedings of the fourth international AAAI conference on weblogs and social media*, Washington D.C., USA.

Turney, P. (2002). Thumbs up or thumbs down? Semantic orientation applied to unsupervised classification of reviews. In *Proceedings of the 40th annual meeting on association for computational linguistics*.

# Part II
# Applications

# The Virtual Experience Economy: A Service-Dominant Logic Perspective

**Eman Gadalla, Kathy Keeling, and Ibrahim Abosag**

## 1 Introduction

Academics and practitioners recognize the need for a deeper understanding of the role of customer experiences in marketing phenomena (Edvardsson, Gustafsson, & Roos, 2005; Holbrook & Hirschman, 1982; Tynan & McKechnie, 2009). In this context, 3D3C worlds (Sivan, 2008) provide sites for engaging consumers in deeper and more sustaining ways, suggesting an important role in providing customer experience. 3D3C worlds provide interactive customer experiences to educate, entertain, display information, or offer an appealing visual aesthetic encounter.

We see a conjunction of the development of experience marketing with the emerging concept of service-dominant logic (S-D logic). A foundational premise of S-D logic is that the customer is always a collaborator in the co-creation of value. Previous writers connect collaboration and value co-creation with the concept of customer experience, a conclusion important for S-D logic and marketing (Pine & Gilmore, 1999; Smith & Wheeler, 2002; Vargo & Lusch, 2004). As a topic, S-D logic has moved in a relatively short time to the forefront of marketing research. Nonetheless, although for S-D logic "*information technology is a pivotal force*" (Lusch, Vargo, & O'Brien, 2007: 11), existing research focuses mainly on S-D logic within the offline context. Despite the growing concept of the experience economy (Pine & Gilmore, 1998) and the development of customer experience

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frameworks in offline contexts (e.g., Verhoef et al., 2009), 3D3C world retailers are still short of such frameworks.

We argue that the concepts of service-dominant logic present a means to reframe and improve experience marketing for increased relevance and impact within 3D3C worlds, and develop an integrated conceptual framework for the virtual experience grounded in this concept.

## 2 Service-Dominant Logic

### *2.1 Principles of Service-Dominant Logic*

Originally devised as ten foundational premises (FPs), a re-organisation now presents four foundational axioms underpinning S-D logic, from which the other FPs result (see Table 1) (Lusch & Vargo, 2014; Vargo & Lusch, 2008). Vargo and Lusch (2004) assert that S-D Logic is a "reorientation rather than reinvention", indicating that adoption does not mean the negation of traditional core marketing concepts, such as the marketing mix, target marketing, market segmentation.

**Table 1** Service dominant logic foundational premises and axioms

| Ten foundational premises (FPs) | Axiom explanation |
|---|---|
| (FP1)/Axiom 1 Service is the fundamental basis of exchange | The application of operant resources (knowledge and skills) "service," is the basis for all exchange.<br>Service is exchanged for service. |
| (FP2) Indirect exchange masks the fundamental nature of exchange | |
| (FP3) Goods are distribution mechanism for service provision | |
| (FP4) Operant resources are the fundamental source of competitive advantage | |
| (FP5) All economies are service economies | |
| (FP6)/Axiom 2 The customer is always a co-creator of value | Implies value creation is interactional. |
| (FP7) The enterprise cannot deliver value, but only offer value propositions | |
| (FP8) A service-centered view is inherently customer oriented and relational | |
| (FP9)/Axiom 3 All economic and social actors are resource integrators | Implies the context of value creation is networks of networks (resource integrators). |
| (FP10)/Axiom 4 Value is always uniquely and phenomenologically determined by the beneficiary | Value is idiosyncratic, experimental, contextual, and meaning-laden. |

*Source*: Lusch and Vargo (2014: 7), Vargo and Lusch (2008)

The principal tenet of S-D logic is that *service* is the fundamental basis of exchange. 'Service' is an interactive process of "doing something for someone" that is valued. *Service* (in the singular) is the core concept replacing both goods and services, defined as "*the application of specialized competences (operant resources—knowledge and skills), through deeds, processes, and performances for the benefit of another entity or the entity itself*" Vargo and Lusch (2004: 2). Simply, service involves applying resources for the benefit of others or oneself. This mind-set is applicable to business organizations, government organizations, non-profit organizations, households, and individuals (Lusch & Vargo, 2014).

S-D logic rejects the common distinction between goods and services (i.e., alternative forms of products) and there is no good-versus-service winner or loser in S-D logic (Lusch & Vargo, 2006). Service is what is always exchanged; it represents the common denominator of any exchange process. Goods, when provided, are aids to the service-provision process (Vargo & Lusch, 2008). Table 2 presents the essentials of S-D logic.

S-D logic views resources as anything an actor can draw on for support (Vargo & Lusch, 2004). Vargo and Lusch (2008) highlight the importance of *operant* resources (FP4) (as distinct from *operand*), which are typically human (skills and knowledge of customers and employees), organizational (routines, cultures, competencies), informational (knowledge about markets, competitors, and technology), and relational (relationships with competitors, suppliers, and customers) (Hunt & Derozier, 2004). Operand resources are typically physical (raw materials or physical products and static in nature, while operant resources are dynamic and can be rejuvenated and replenished. In S-D logic, knowledge is the operant resource, the foundation of competitive advantage and the only sustainable source of wealth. All social and economic actors are resource integrators (FP9) (Vargo & Lusch, 2008). Baron and Harris (2008) provide insights into the process of consumer resource

**Table 2** Conceptual transitions

| Goods-dominant logic concepts | Transitional concepts | Service-dominant logic concepts |
|---|---|---|
| Goods | Services | Service |
| Products | Offerings | Experiences |
| Feature/attribute | Benefit | Solution |
| Value-added | Co-production | Co-creation of value |
| Profit maximization | Financial engineering | Financial feedback/learning |
| Price | Value delivery | Value proposition |
| Equilibrium systems | Dynamic systems | Complex adaptive systems |
| Supply chain | Value-chain | Value-creation network/ constellation |
| Promotion | Integrated marketing communications | Dialog |
| To market | Market to | Market with |
| Product orientation | Market orientation | Service orientation |

*Source*: Lusch and Vargo (2006: 286)

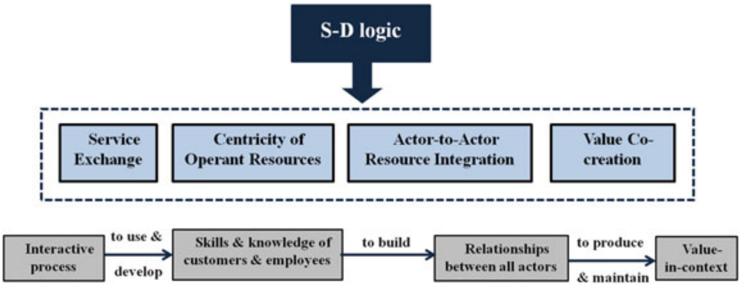



**Fig. 1** Summary of S-D logic perspective

integration through which consumers are effective participants in shaping their own experience. Jointly created value surpasses that which results from each actor alone.

Another S-D logic tenet is the *conceptualization of value and value creation*. Value is traditionally viewed as embedded in a product that is exchanged on basis of value-in-exchange. Vargo and Lusch (2004) propose that the firm cannot create value but can only offer value propositions (FP7) and then collaboratively create value with the participants (FP6). Value only occurs when the offering is useful to the customer or beneficiary (value-in-use), mediated and monitored by value-in-exchange and this is always value-in-context (Vargo & Lusch, 2008). This shift in the locus of value creation requires transforming our understanding of value from one based on outputs to one based on processes that integrate resources of different actors. Thus, all participants in the value-creation process, including customers, are dynamic operant resources, capable of creating value. Value is always uniquely and phenomenologically determined by the beneficiary (FP10), consequently customers must be the main source of value creation (Lusch & Vargo, 2006) and value is idiosyncratic, experiential, contextual and meaning-laden (Vargo, 2009; Vargo & Lusch, 2008). Figure 1 reflects a summary of these ideas.

Some relevant literature focuses on the refinement of S-D logic theoretical frameworks (Ballantyne & Varey, 2008; Vargo & Lusch, 2008), and co-creation and co-production (e.g. Etgar, 2008; Payne, Storbacka, & Frow, 2008; Xie, Bagozzi, & Troye, 2008). Most apposite to this chapter, Zwass (2010) proposes an inclusive taxonomy of Web-based co-creation. Though drawn upon multiple literatures, none of these have linked or investigated S-D logic within the context of the 3D3C worlds.

## 2.2 *Service-Dominant Logic and 3D3C Worlds*

Naturally, any application of S-D logic in 3D3C worlds cannot be made without proper consideration for the nature of the platform that produces the 3D3C environment. Very recently, Vargo and Lusch (2014: 3) emphasize that "*the overall* *narrative of S-D logic, at least in its present state, becomes one of (generic) actors co-creating value through the integration of resources and exchange of service, coordinated through actor-engendered institutions in nested and overlapping service ecosystems*." The distinctive characteristics of 3D3C worlds and their similarities with real life allow actors within 3D3C worlds to co-create value through an integrated system of resources. Hence, we believe that the virtual experience can be better and more accurately understood by defining its nature and scope using a service-dominant-informed perspective. In order to show the relevance of S-D logic within 3D3C worlds, Table 3 links the S-D logic premises to the context of 3D3C worlds.

**Table 3** Axioms of S-D Logic and its application to 3D3C worlds

| Premise | Explanation | Application to 3D3C worlds |
|---|---|---|
| FP1/Axiom 1: Service is the fundamental basis of exchange | The application of operant resources (knowledge and skills) "service" is the basis for all exchange. Service is exchanged for service. | Customers, virtual retailers and 3D3C worlds providers exchange knowledge and skills to improve service offerings in particular and virtual experience in general. |
| FP6/Axiom 2: The customer is always a co-creator of value | Implies value creation is interactional. | 3D3C worlds represent a community where people work, play and act together. Hence, important for 3D3C world providers and virtual retailers to interact with and understand their customers' virtual practice/life/behavior and their specific requirements while developing virtual experiences and delivering their service offerings. This can only be achieved through value co-creation. |
| FP9/Axiom 3: All economic and social actors are resource integrators | Implies the context of value creation is networks of networks (resource integrators). | Social and economic actors integrate various types of resources to create value. This represents the relationships built between all the actors to engage is a resource integration process through co-creating value. Virtual retailers and 3D3C providers have an essential role to play in such integration. |
| FP10/Axiom 4: Value is always uniquely and phenomenologically determined by the beneficiary | Value is idiosyncratic, experimental, contextual, and meaning-laden. | In the context of 3D3C worlds, the same offerings will provide different value to different customers, dependent upon their motivation for using the virtual context. |

Since the nature of S-D logic is influenced by the type of environment and context within which services are designed, produced and delivered, the axioms of S-D logic as determined and influenced by 3D3C worlds context are as follows:

- Axiom 1: service is the most fundamental basis of exchange. Within 3D3C worlds, customer, virtual retailers and the providers of 3D3C worlds exchange knowledge, skills and resources in order to provide an enjoyable virtual experience and improve service quality and offerings.
- Axiom 2: customers are co-creators of value through continuous interaction between all actors. Within 3D3C worlds, interaction includes the entire community within which virtual retailers and 3D3C world providers must develop their understanding and knowledge of customers' needs and wants. Such interaction and understanding will allow virtual retailers and 3D3C world providers to offer a remarkable virtual experience that facilitates customer engagement in value co-creation. This engagement is vital for all actors within the community.
- Axiom 3: all actors, both social and economic actors, are integrators of resources through network integration that allows for value creation. Within 3D3C worlds, the role of both the virtual retailer and 3D3C providers is essential in driving and enabling the integration of resources to create value for both social and economic actors.
- Axiom 4: value is always unique and determined by the beneficiary. Such value is dependent on the experience, the context and meaning constructed by the beneficiary and valued through that personal lens. In 3D3C worlds, the uniqueness of value is similarly determined by the beneficiary but their motives are shaped by the virtual context within which such experience and meaning are perceived and profoundly judged. Thus, the virtuality of 3D3C world is also an influencer of value and value uniqueness.

The process of value creation is rapidly shifting from a product-and firm-centric view to personalized consumer experiences (Prahalad & Ramaswamy, 2004). Prahalad and Ramaswamy (2004) posit that co-creation converts the market into a forum for dialogue among the consumer, the firm, consumer communities, and networks of firms. Such activities of co-creation are essentially driven by the experience as perceived and felt by actors within the market where interactions take place. In return, the type of marketing experience enhances and encourages further engagement in the process of value co-creation. Thus, understanding experiential marketing within different contexts is important to the process of co-creation.

## 3 Conceptualization of Experience in 3D3C Worlds Using S-D Logic

This section reviews the concept of experiential marketing, then uses S-D logic can to reframe experience marketing for improved relevance to 3D3C worlds.

### *3.1 Experiential Marketing*

Although introduced in the business field by Pine and Gilmore (1998), it was Holbrook and Hirschman (1982) who theorized that consumption has experiential aspects (see also Babin, Darden, & Griffin, 1994). Holbrook and Hirschman (1982) felt that consumer research neglected important consumption phenomena involving fantasies, fun, aesthetic enjoyment, and emotional responses. The experiential view of marketing emphasizes the symbolic meaning, subconscious processes, and nonverbal cues resulting from consumption.

Experience marketing is a relatively recent concept popular in different fields such as tourism (Leighton, 2007), retailing (Grewal, Levy, & Kumar, 2009; Verhoef et al., 2009), branding (Brakus, Schmitt, & Zarantonello, 2009; Gentile, Spiller, & Noci, 2007), entertainment and arts (Petkus, 2004). Within this chapter, we will focus on customer experience within the retailing field.

Consumer and marketing research on experience marketing is still emerging (Schmitt & Zarantonello, 2013) with key contributions by Carbone and Haeckel (1994), Pine and Gilmore (1998), Gilmore and Pine (1997) and Schmitt (1999, 2003, 2011). Popular management books (e.g., Pine & Gilmore, 1999) emphasize that firms must focus on customer experience, differentiation strategies based on service and price are no longer sufficient. Schmitt (1999) differentiates experiential marketing from traditional marketing on four characteristics: a focus on customer experience, a focus on consumption as a holistic experience, customers are rational and emotional animals, and methods and tools are eclectic. However, despite contributions to advance theory, knowledge and understanding on experiential marketing (Arnold & Reynolds, 2003; Carù & Cova, 2003; Grewal et al., 2009; Verhoef et al., 2009), the literature is arguably still in its early stages toward the development of a comprehensive theory/framework of experiential marketing as determined and conditioned by different contexts and environments.

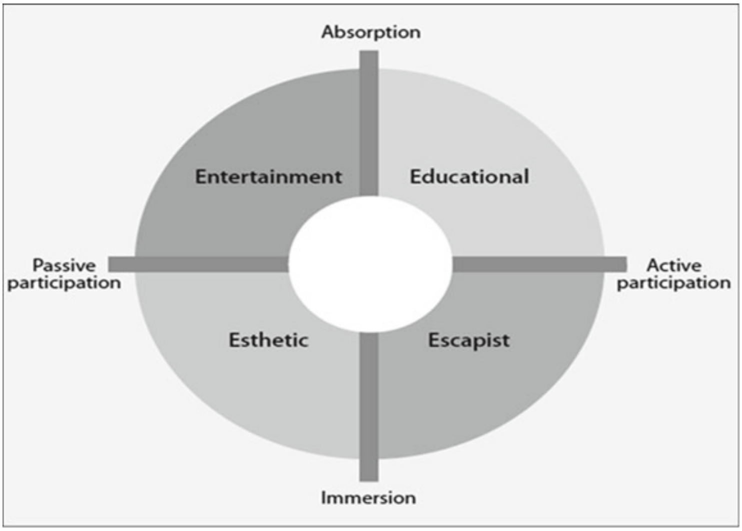
Experience marketing is generally based on experience economy theory. Pine and Gilmore (1998) claim experiences to be the fourth economic offering (see Table 4). These authors explain the progression of value from commodities to experiences by showing how experiences differ from goods and services. Table 4 explains the Pine and Gilmore (1998) perspective and emphasizes how economic value at a societal level has progressed through three stages, and that we are entering a fourth stage: the experience economy.

Note the existing diversified relevant terminology of the term ‘experience’ in marketing and management literature, such as “experience economy” (Pine & Gilmore, 1998), “experiential marketing” (Schmitt, 1999), “entertainment economy” (Wolf, 1999), “a dream society” (Jensen, 1999), “emotion economy” (Gobé & Zyman, 2001), and “attention economy” (Davenport & Beck, 2002).

**Table 4** Economic distinctions

| Economic offering | Commodities | Goods | Services | Experiences |
|---|---|---|---|---|
| Economy | Agrarian | Industrial | Service | Experience |
| Economic function | Extract | Make | Deliver | Stage |
| Nature of offering | Fungible | Tangible | Intangible | Memorable |
| Key attribute | Natural | Standardized | Customized | Personal |
| Method of supply | Stored in bulk | Inventoried after production | Delivered on demand | Revealed over a duration |
| Seller | Trader | Manufacturer | Provider | Stager |
| Buyer | Market | User | Client | Guest |
| Factors of demand | Characteristics | Features | Benefits | Sensations |

*Source*: Adaptation of Pine and Gilmore (1998)




Source: Pine and Gilmore (1998, 102)

**Fig. 2** The four realms of a consumption experience. *Source*: Pine and Gilmore (1998: 102)

Pine and Gilmore (1998) conceptualize experiences across two dimensions: customer participation (active/passive) and the connection, or environmental relationship (absorption/immersion), that unites customers with the event or performance. Pine and Gilmore (1998, 1999) define the four realms or so called "four Es" of a consumption experience: entertainment, educational, escapist, and (a)esthetic, by using these two dimensions (see Fig. 2). Experience marketing creates emotions in the consumer through entertainment, escape from the reality, education or giving them aesthetic objects or places to see (Pine & Gilmore, 1999). Companies can stage an experience whenever they engage customers in a personal, memorable way (Pine & Gilmore, 1998).

With this background, we consider the potential for customer experience in the rapidly growing context of 3D3C worlds.

## 3.2 *The Logic of Experiential Marketing in 3D3C Worlds Is Different*

To extend the work by Pine and Gilmore (1998) to 3D3C worlds, Table 5 shows first how the four realms of the experience in the traditional offline context can fit into and directly be applied to 3D3C worlds. Second, areas of irrelevance or inconsistency are evident, so we raise questions concerning the relevance of the Pine and Gilmore's (1998) conceptualization to 3D3C worlds. The critique is based on the following two arguments:

- First, Pine and Gilmore (1998) believe customer participation is one dimension that characterizes the experience, we agree that participation and interaction is vital but we reject the divide between passive and active participation. We believe all users are active participants creating their own experiences because even if they are not interacting with other users, they are interacting with the virtual environment itself or even with their own avatar. They affect the virtual experience by just being present in the 3D3C worlds because without this presence, the virtual world will be empty.
- Second, according to Pine and Gilmore (1998), the connection with the environment is another dimension that characterizes the experience. Acknowledging the importance of this connection, nevertheless, we reject the divide between absorption and immersion. The virtual experience is all about immersion. Being an immersive context is one of the main features that define 3D3C worlds.

Clearly, differences between environments and contexts must be taken into account when marketers consider customer experience. Table 5 provides a detailed discussion on the Pine and Gilmore (1998) conceptualization, highlighting gaps that necessitate a fresh view about 3D3C worlds. S-D logic can provide a broader conceptualization of 3D3C worlds without limiting it to the Pine and Gilmore (1998) dimensions (i.e., passive/active versus absorption/immersion).

**Table 5** The four realms of experience marketing by Pine and Gilmore (1998) and its applications to the 3D3C worlds

| The four realms of the experience by Pine and Gilmore (1998) | Direct applications to 3D3C worlds | Evaluation/review in 3D3C worlds context: Raising questions to identify areas of irrelevance or inconsistency |
|---|---|---|
| **Entertainment**: **Passive Participation Absorption** Such as watching television, attending a concert—tend to be those in which customers participate more passively than actively; their connection with the event is more likely one of absorption than of immersion. | Tend to be those avatars who limit their experience to being an 'avatar' without actively taking part in any consumption or virtual activities. | **Can Entertainment in 3D3C worlds take place with passive participation and absorption?** First, the virtual experience is all about being active, even if users are not interacting with other actors and participating in any event, they are considered active participants as they actively choose their appearance and even interact with their own avatars. Additionally, they interact with the environment itself and their own appearance and existence within the environment can affect the experience of others. Second, any virtual level of interaction mainly takes place to improve the sense of presence and immersion, users use 3D3C worlds to immerse themselves in an enjoyable and entertaining context. **Therefore, it is not about consuming products but rather it is about consuming the experience itself, which can occur only if users are active and immersed in the virtual context.** |
| **Educational: Active Participation Absorption** Such as attending a class, taking a ski lesson—tend to involve more active participation, but students (customers, if you will) are still more outside the event than immersed in the action. | Tend to be those avatars who are more active in acquiring and learning without immersing themselves in events. For example, using Xstreet to shop instead of looking for information within the environment. | **Can avatars acquire information or buy products without immersing themselves in the environment?** First, for example if users prefer to buy products from Xstreet, at some stage after buying what they need, they will return to the virtual environment to consume their products virtually. Therefore, |

(continued)

**Table 5** (continued)

| The four realms of the experience by Pine and Gilmore (1998) | Direct applications to 3D3C worlds | Evaluation/review in 3D3C worlds context: Raising questions to identify areas of irrelevance or inconsistency |
|---|---|---|
| | | it is not absorption any more as the use of the purchased product within the virtual context will increase the level of immersion.<br>Second, even if we took attending a class as an example, one reason of delivering online virtual classes is to increase the level of immersion, which in return can improve students' learning process. Hence, avatars in a virtual learning environment are not considered outsiders to the event.<br>**Therefore, it is very reasonable to assume that active participation and immersion are essential for an enjoyable virtual experience.** |
| **Escapist:**<br>**Active Participation Immersion**<br>Escapist experiences teach equally as well as educational events, or amuse just as well as entertainment, but involve greater customer immersion. Acting in a play, or descending the Grand Canyon involve both active participation and immersion in the experience | Tend to be those active avatars that engage their real life needs to 3D3C worlds. Users are involved in interaction with others and/or virtual consumption. They are active participants in experiences that may not be doable/applicable in real life. Hence, they immerse themselves in a virtual life and invest time in interacting with different users. | **This pillar reflects to a great extent the current state of 3D3C worlds but raises two important issues:**<br>First, active participation within 3D3C worlds is necessary for any virtual experience though to better conceptualize 3D3C worlds, it is important to distinguish the different types of interaction. In 3D3C worlds, users can interact and influence the virtual context as well as interact with other avatars.<br>Second, the connection with the environment is considered a simple and superficial way to characterize the virtual experience when focusing on immersion without recognizing the different contexts of interaction that might take place (i.e. the |

(continued)

**Table 5** (continued)

| The four realms of the experience by Pine and Gilmore (1998) | Direct applications to 3D3C worlds | Evaluation/review in 3D3C worlds context: Raising questions to identify areas of irrelevance or inconsistency |
|---|---|---|
| | | effect of real life). The interplay with real life is vital as 3D3C worlds do not exist in isolation. **Hence, it is important to define the virtual experience in a broader view taking into consideration possible types and contexts of interaction between different users.** |
| **Esthetic: Passive Participation Immersion** Participants immersed in activity or environment, but they themselves have little or no effect on it—as a tourist who views the Grand Canyon from its rim or a visitor to an art gallery. | Avatars who generally enjoy the 3D virtual context or particularly the creative atmospherics/aesthetics. They enjoy how the virtual context stands out from real world and immerse themselves with the virtual surroundings and the beauty attained from living virtually. | **Can Immersion take place with passive participation?** Although these avatars are not necessarily engaged in buying behavior, they are consuming the virtual context itself, the surroundings, and the beauty of atmospherics around them. Avatars are part of the virtual context by walking, running and flying around from one place to another. **Hence, all users should be considered as active participants even if they are only interacting with the virtual environment.** |

## 4 Re-framing Experience Marketing in 3D3C Worlds Using S-D Logic

Recent research stresses the importance of the virtual consumption experience (e.g. Jung & Pawlowski, 2014). Yet, less is known about the holistic nature of the virtual experience. The adoption of S-D logic enables us to devise a holistic perspective to overcome inconsistencies identified in the previous section. Building on Pine and Gilmore (1998), we offer a broadened view of virtual experience marketing guided by service-dominant logic. With value, as determined by the

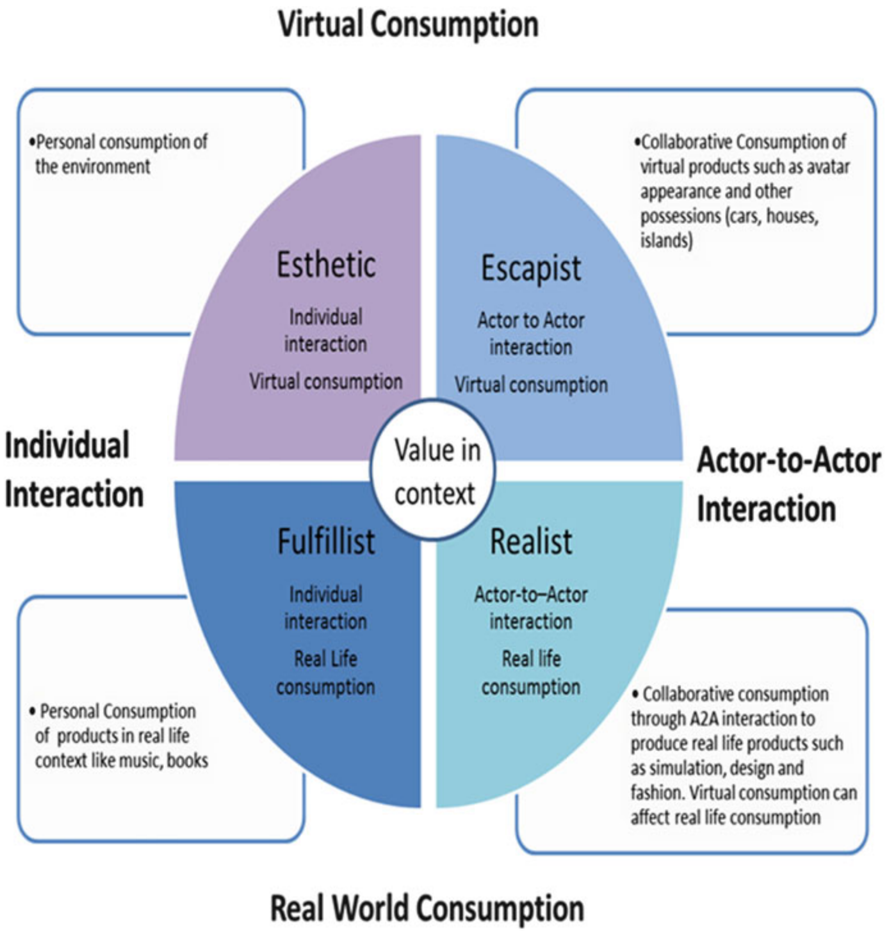



**Fig. 3** The four pillars of a virtual experience

context (value in-context), in the centre of the virtual consumption experience, virtual experience can be understood across two dimensions (see Fig. 3):

1. Type of Interaction: where at one end of the spectrum lies individual interaction (i.e., interaction with the environment). At the other end of the spectrum lies Actor-to-Actor interaction (e.g., interaction with other avatars; interaction with in-world companies).
2. Type of Consumption (Context of Interaction): where at one end of the spectrum lies virtual consumption, at the other end, real life consumption.

### 4.1 Type of Interaction: Individual Versus Actor-to-Actor Interaction

Two types of interactions form the basis of the virtual experience that will lead to resource integration within 3D3C worlds: individual where users interact with the virtual context and actor-to-actor interaction where users interact with different actors. From an S-D logic perspective, all social and economic actors are resource integrators (FP9/axiom 3). There are three different actors: customers, virtual retailers and providers of 3D3C worlds. The three actors are involved in economic exchange through resource-integration. Consistent with S-D logic, the traditional divide between consumers and producers is not applicable within the virtual context.

For individual interaction, the contents of a 3D3C world such as Second Life are created by the users. Users are empowered to freely create and control their environment. "*To me, that's the beauty of Second Life: all we've created is a platform, an almost empty world; where we got lucky is in the fact that you [users] came along and breathed life into it. If Second Life is a world at all, it's because you've created it*." (Philip Rosedale, quoted in Rymaszewski et al., 2006: iv). Each consumer in Second Life brings a set of creative skills and capabilities that, when effectively used, produces superior resources/services/offerings to the Second Life community (all other actors). Linden Lab has embraced the interactive consumer through the open nature of its user platforms. Interactions with the context range from interacting with existing offerings simply to enjoy them or to create something new, e.g., choosing and clothing an avatar from an existing range, to full scale adaptation and creation of entirely new virtual goods and landscapes. Virtual worlds afford a much greater opportunity for co-creation, since the players actually create the world (Zwass, 2010).

Generally, virtual worlds allow people to come together virtually and engage with each other. Hence, the second type is actor-to-actor interaction. Vargo and Lusch (2011) use a generic "Actor-to-Actor" (A2A) designation, emphasizing that actors are constantly dropping and forming new connections; contexts, thus are always in flux and the experience of value is dynamic. This is evident in the context of 3D3C worlds. Fetscherin and Lattermann (2008) argue that cooperation and communication are the most important determinants of virtual worlds. Similarly, Papagiannidis and Bourlakis (2010) confirm that the distinctive active-avatar, participatory-based approach provides a unique experience wherein users can co-create their experience whilst fulfilling needs for self-expression, identity, and social interaction with others. This is relevant to the concept of the customer as always a collaborator; both a foundational premise (FP6/axiom 2) of S-D logic and a main component of the virtual experience.

### 4.2 *Context of Interaction: The Interplay Between Virtual and Real Life Contexts*

The context of interaction is the second dimension that shapes the virtual experience. First, virtual consumption is one of the popular activities that attracts different customers. Much purchasing in 3D3C worlds is of digital goods, fulfillment is immediate and these goods are also mostly ‘consumed’ in the 3D context. The distinct characteristic of virtual goods and services (virtual items, characters, currencies, premium memberships) is that they do not have a clear atomistic equivalent or component in them (Fairfield, 2005), and they can only be consumed and have value inside a specific virtual environment. Kish (2007) indicates that trusted relationships, both personal and professional, emerge quickly in these environments and can carry over into the real world. Thus, using a holistic approach, dictates that we go beyond the virtual consumption context to consider the interplay with real life.

Second is the real life context. The virtual experience (e.g. behavior and activities within the 3D3C world context) is not isolated from the rest of the electronic space or the real world itself (Castronova, 2005), there is interplay between virtual and real-world purchasing behavior. Although virtual products do not have physical existence; they exist digitally and socially (Brey, 2003), appearing to us as physical objects that we interact with in a manner similar to real physical objects (Brey, 2014). Moreover, Jung and Pawlowski (2014) suggest that users see their virtual activities as reflecting their social experiences in real life. Nah, Eschenbrenner, and DeWester (2011) demonstrate that pleasurable experiences with a brand in the virtual world translate into a willingness to also engage with the brand in the offline setting and Shelton (2010) finds motivations for using Second Life correlate with the purchasing of both virtual and real-life products. Bainbridge (2014) supports this user perception that virtual consumption is somehow equivalent to real-world consumption (Jung & Pawlowski, 2014), explaining that 3D3C worlds are larger than they might seem, because the social life they support extends to wikis and other forms of online communication and also to memory. Nevertheless, there are differences, for example, virtuality differentiates hedonic consumption in the virtual context from the real-world context due to the relaxation/removal of constraints (e.g. cultural, social, personal and structural) and users more freely express their individuality within a complex world (Bainbridge, 2014; Jung & Pawlowski, 2014).

To sum, it is important to consider the holistic customer experience taking into consideration all possible types of interactions between all actors that might take place in different contexts. From this perspective, the interaction between the extremes of the two dimensions as in Fig. 3 produces the following four pillars:

- The first pillar is concerned with ‘esthetic’ resulting from the synergy between individual interaction and virtual consumption. The value in context produced by this segment stems from the focus on the self and personal consumption of the environment where consumers engage freely with their virtual environment and

**Fig. 4** The 'esthetic': interacting with and consuming the beauty of the virtual context

construct the experience they enjoy most (see Fig. 4). This allows customers to experience the virtual environment the way they want. This segment represents the simple form of interaction within 3D3C worlds. Actors within this segment are interested in consuming the beauty of the virtual context over socializing with other actors. They appreciate the effort and time taken in creating the virtual context such as Hype Park, creative architecture, attractive store designs. Hence, as an 'escapist' shopping for virtual products, the first thing that will attract them to virtual stores is beautiful, creative and novel designs.

- The second pillar concerns the interface between actor-to-actor interaction and virtual consumption. The value in context is shaped by the 'escapist' collaborative consumption of virtual products. In addition to virtually consuming the environment (i.e., 'esthetic' grouping), actors in this segment are interested in virtual ownership of digital products as well (see Fig. 5). Hence, actors within this segment could be both 'escapist' and 'esthetic'. Interaction within this segment allows actors to express their individuality and virtual persona as they desire. Such interactions influence the way actors feel about their avatar appearance or the appearance of other possessions such as cars, islands, furniture, houses, etc. Offering aesthetically pleasing, up-to-date stores and an appropriate variety of digital products represents a straightforward approach for virtual retailers to attract actors within this segment.
- The third pillar concerns fulfilling personal needs for real products. Value-in-context is shaped by a customer desire to generate their own experience and fulfillment through the consumption of real products, such as books or music but through a virtual world (see Fig. 6). The customer may have fulfilled some other need concurrently, such as, 'aesthetic': enjoying the architecture and design of a virtual bookshop and/or 'escapist': buying virtual books to decorate his/her virtual house. Paradoxically, this mixture of virtual and 'real' consumption

**Fig. 5** The escapist: buy virtual products for avatars, this store sell virtual shoes that have programming for dances or other movement

may mean these consumers are especially engaged within 3D3C worlds as they are choosing to stay within the virtual to fulfill 'real world' consumption. This is an interesting segment for virtual retailers as providing for such duality of consumption can extend the present 2D online store experience and the offline bricks and mortar experience. Virtual retailers might consider providing such virtual store experiences within bricks and mortar stores, with all the capacity for offering unique experiences and settings, e.g., for bookstores, interactions with historical writers and environments, or re-creation of historical libraries within which to make purchases (imagine interacting with a Greek philosopher in the library at Alexandria).

- The fourth pillar is related to the actor-to-actor interaction as influenced by real life consumption. The value-in-context stems from the 'realist' collaborative consumption through the interaction of actor-to-actor to produce real products for real life consumption and/or to host events for real life causes (see Fig. 7). Such products are likely to be simulations, or related to design or fashion. There is a possible link here with the second pillar as virtual consumption can affect, motivate and inform real life consumption (Jung & Pawlowski, 2014). This segment represents the highest and most complicated form of interaction given the interplay with the real life context.

## *4.3 Value in Context: Co-creation of Experiential Value*

We have consistently acknowledged throughout this chapter that an S-D logic approach means that firms cannot deliver value; they can only offer a value proposition as an invitation to engage with the firm (and potentially other actors) for the co-creation of value. Vargo (2011) claims the closer the relationship


**Fig. 6** The fulfillist: fulfilling personal needs for real products such as listening to music in-world and downloading to your computer

between customers and providers, the more the emphasis of the value proposition can be placed on value-in-use. From an S-D logic perspective, value is always uniquely and phenomenologically determined by the beneficiary (FP10/axiom 4). Therefore, value-in-context is the center of the virtual experience, particularly, we also acknowledge that experiential value is a fundamental concept in experience marketing (Schmitt & Zarantonello, 2013) and that such experiential value resides in seeking out and processing information, and also importantly in the experience of consumption (Schmitt & Zarantonello, 2013). So, we argue that within 3D3C worlds, experiential values are achieved through different types of interaction in both virtual and real life contexts. Verhagen, Feldberg, Van den Hooff, Meents, and Merikivi (2011) confirm that experiential value is a strong and direct determinant of users' satisfaction with virtual worlds, but Barnes (2011) emphasizes that whilst hedonic interactions are important, this is not at the expense of utilitarian benefits. Similarly, we posit that, in 3D3C worlds both types of values (utilitarian and experiential) mutually affect each other and the absence of either will negatively


**Fig. 7** The Realist: hosting events for real life causes such as making strides against breast cancer to raise awareness about breast cancer

affect the virtual experience; however, it is the presence of the experiential benefits that provides a remarkable experience.

To conclude, we claim a particular relevance of S-D logic for experience marketing as it provides a broad-spectrum perspective that integrates: the type of interaction (i.e., the co-creator of the experience who interacts either the virtual environment and/or with other actors), the context of interaction (i.e., the interplay with real life: how the virtual might affect the real life context), and how these two dimension offer experiential values gained through immersing in the context of 3D3C worlds. Retail (and other) organizations can reflect on the possibilities offered by each segment to produce compelling value propositions, bearing in mind that they are not mutually exclusive.

## References

Arnold, M. J., & Reynolds, K. E. (2003). Hedonic shopping motivations. *Journal of Retailing, 79*(2), 77–95. doi:10.1016/S0022-4359(03)00007-1.

Babin, B. J., Darden, W. R., & Griffin, M. (1994). Work and/or fun: Measuring hedonic and utilitarian shopping value. *Journal of Consumer Research, 20*(4), 644–656.

Bainbridge, W. S. (2014). *Personality capture and emulation, human-computer interaction series*. London: Springer.
Ballantyne, D., & Varey, R. J. (2008). The service-dominant logic and the future of marketing. *Journal of the Academy of Marketing Science, 36*(1), 11–14.
Barnes, S. J. (2011). Understanding use continuance in virtual worlds: Empirical test of a research model. *Information & Management, 48*, 313–319.
Baron, S., & Harris, K. (2008). Consumers as resource integrators. *Journal of Marketing Management, 24*(1–2), 113–130.
Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand experience: What is it? How is it measured? Does it affect loyalty? *Journal of Marketing, 73*, 52–68.
Brey, P. (2003). The social ontology of virtual environments. *American Journal of Economics and Sociology, 62*, 269–282.
Brey, P. (2014). The physical and social reality of virtual worlds. In M. Grimshaw (Ed.), *The oxford handbook of virtuality* (pp. 42–54). New York: Oxford University Press.
Carbone, L. P., & Haeckel, S. H. (1994). Engineering customer experiences. *Marketing Management, 3*(3), 8–19.
Carù, A., & Cova, B. (2003). Revisiting consumption experience. *Marketing Theory, 3*(2), 267–286.
Castronova, E. (2005). *Synthetic worlds: The business and culture of online games*. Chicago: University of Chicago Press.
Davenport, T. H., & Beck, J. C. (2002). *The attention economy*. Boston: Harvard Business School Press.
Edvardsson, B., Gustafsson, A., & Roos, I. (2005). Service portraits in service research: A critical review. *International Journal of Service Industry Management, 16*(1), 107–121.
Etgar, M. (2008). A descriptive model of the consumer co-production process. *Journal of the Academy of Marketing Science, 36*(1), 97–108.
Fairfield, J. (2005). Virtual property. *Boston University Law Review, 85*, 1047–1102.
Fetscherin, M., & Lattermann, C. (2008). User acceptance of virtual words. *Journal of Electronic Commerce Research, 9*(3), 231–242.
Gentile, C., Spiller, N., & Noci, G. (2007). How to sustain the customer experience: An overview of experience components that co-create value with the customer. *European Management Journal, 25*(5), 395–410.
Gilmore, J., & Pine, J. (1997). Beyond goods and services. *Strategy and Leadership, 25*(3), 10–17.
Gobé, M., & Zyman, S. (2001). *Emotional branding: The new paradigm for connecting brands to people*. New York: Allworth Press.
Grewal, D., Levy, M., & Kumar, V. (2009). Customer experience management in retailing: An organizing framework. *Journal of Retailing, 85*(1), 1–14.
Holbrook, M. B., & Hirschman, E. C. (1982). The experiential aspects of consumption: Consumer, fantasies, feelings, and fun. *Journal of Consumer Research, 9*(September), 132–140.
Hunt, S. D., & Derozier, C. (2004). The normative imperatives of business and marketing strategy: Grounding strategy in resource advantage theory. *Journal of Business & Industrial Marketing, 19*(1), 5–22.
Jensen, R. (1999). *The dream society: How the coming shift from information to imagination will transform your business*. New York: McGraw-Hill.
Jung, Y., & Pawlowski, S. D. (2014). Understanding consumption in social virtual worlds: A sense making perspective on the consumption of virtual goods. *Journal of Business Research, 67*(10), 2231–2238.
Kish, S. (2007). *Second life, virtual worlds and the enterprise*. Retrieved June 25, 2014, from http://skish.typepad.com/susan_kish/secondlife/SKish_VW-SL_sept07.pdf
Leighton, D. (2007). Step back in time and live the legend: Experience marketing and the heritage sector. *International Journal of Nonprofit and Voluntary Sector Marketing, 12*(2), 117–125.
Lusch, R. F., & Vargo, S. L. (2006). The service-dominant logic of marketing: Reactions, reflections, and refinements. *Marketing Theory, 6*(3), 281–288.

Lusch, R. F., & Vargo, S. L. (2014). *Service-dominant logic: Premises, perspectives, possibilities*. Cambridge: Cambridge University Press.
Lusch, R. F., Vargo, S. L., & O'Brien, M. (2007). Competing though service: Insights from service-dominant logic. *Journal of Retailing, 83*(1), 5–18.
Nah, F. F., Eschenbrenner, B., & DeWester, D. (2011). Enhancing brand equity through flow and telepresence: A comparison of 2D and 3D virtual worlds. *MIS Quarterly, 35*(3), 731–747.
Papagiannidis, S., & Bourlakis, M. (2010). Staging the new retail drama: At a Metaverse near you! *Journal of Virtual Worlds Research, 2*(5), 4–17.
Payne, A. F., Storbacka, K., & Frow, P. (2008). Managing the co-creation of value. *Journal of the Academy of Marketing Science, 36*(1), 83–96.
Petkus, E. J. (2004). Enhancing the application of experiential marketing in the arts. *International Journal of Nonprofit and Voluntary Sector Marketing, 9*(1), 49–56.
Pine, J., & Gilmore, J. (1998, July–August). Welcome to the experience economy. *Harvard Business Review,* 97–105.
Pine, J., & Gilmore, J. (1999). *The experience economy*. Cambridge, MA: Harvard Business School Press.
Prahalad, C. K., & Ramaswamy, V. (2004). *The future of competition: Co-creating unique value with customers*. Boston: Harvard Business School Press.
Rymaszewski, M., Au, W. J., Wallace, M., Winters, C., Ondrejka, C., Batstone-Cunningham, B., et al. (2006). *Second life: The official guide*. Hoboken, NJ: Wiley.
Schmitt, B. (1999). Experiential marketing. *Journal of Marketing Management, 15*(1–3), 53–67.
Schmitt, B. (2003). *Customer experience management: A revolutionary approach to connecting with your customers*. Hoboken, NJ: Wiley.
Schmitt, B. (2011). Experience marketing: Concepts, frameworks and consumer insights. *Foundations and Trends in Marketing, 5*(2), 55–112.
Schmitt, B., & Zarantonello, L. (2013). Consumer experience and experiential marketing: A critical review. In N. K. Malhotra (Ed.), *Review of marketing research* (Vol. 10, pp. 25–61). London: Emerald Group Publishing.
Shelton, A. K. (2010). Defining the lines between virtual and real world purchases: Second life sells, but who's buying? *Computers in Human Behavior, 26*(6), 1223–1227.
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), 1–32.
Smith, S., & Wheeler, J. (2002). *Managing the customer experience*. London: Financial Times Prentice Hall.
Tynan, C., & McKechnie, S. (2009). Experience marketing: A review and reassessment. *Journal of Marketing Management, 25*(5–6), 501–517.
Vargo, S. L. (2009). Toward a transcending conceptualization of relationship: A service-dominant logic perspective. *Journal of Business & Industry Marketing, 24*(5/6), 373–379.
Vargo, S. L. (2011). Market systems, stakeholders and value propositions: Toward a service-dominant logic-based theory of the market. *European Journal of Marketing, 45*(1/2), 217–222.
Vargo, S. L., & Lusch, R. F. (2004). Evolving a services dominant logic for marketing. *Journal of Marketing, 68*, 1–17.
Vargo, S. L., & Lusch, R. F. (2008). Service-dominant logic: Continuing the evolution. *Journal of the Academy of Marketing Science, 36*(1), 1–10.
Vargo, S. L., & Lusch, R. F. (2011). It's all B2B. . .and beyond: Toward a systems perspective of the market. *Industrial Marketing Management, 40*(2), 181–187.
Vargo, S. L., & Lusch, R. F. (2014). Inversions of service-dominant logic. *Marketing Theory, 20*, 1–10. doi:10.1177/1470593114534339.
Verhagen, T., Feldberg, F., Van den Hooff, B., Meents, S., & Merikivi, J. (2011). Satisfaction with virtual worlds: An integrated model of experiential value. *Information & Management, 48*(6), 201–207.

Verhoef, P., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., & Schlesinger, L. A. (2009). Customer experience creation: Determinants, dynamics and management strategies. *Journal of Retailing, 85*(1), 31–41.

Wolf, M. J. (1999). *The entertainment economy—how mega-media forces are transforming our lives*. New York: Random House.

Xie, C., Bagozzi, R. P., & Troye, S. V. (2008). Trying to prosume: Toward a theory of consumers as co-creators of value. *Journal of the Academy of Marketing Science, 36*(1), 109–122.

Zwass, V. (2010). Co-creation: Toward a taxonomy and an integrated research perspective. *International Journal of Electronic Commerce, 15*(1), 11–48.

# Virtual Psychology: An Overview of Theory, Research, and Future Possibilities

**Jennifer Wu and Philipp Kraemer**

## 1 Overview

The development of alternative realities has been an important component of human storytelling since the beginning of civilization. Cave drawings, the printing press, and moviemaking have all been steps to make it easier for us to move our minds out of the real world and into another time, another place, or another world entirely. Technology has consistently expanded and streamlined the ways humans connect their minds to fictional places and fantastical realities. With the invention of the Internet, the creation of alternate realities has increasingly relied on digital technologies (Blascovich & Bailenson, 2011). In that context, this chapter presents a detailed overview of research on Virtual World (VW) psychology: the study of cognitive and social aspects of online behavior in digital environments that simulate aspects of the real world. The type of VWs of interest in this chapter involves those in which users represent themselves with avatars. As an example, Figure 1 offers a snapshot of the kind of simulated environment found in Second Life (SL), one of the more popular avatar-mediated VWs that features over 38 million users.

## 2 Theoretical Framework

The study of VW psychology has concentrated on two kinds of processes: cognitive and social. Each theme has been examined from an array of theoretical perspectives. Research on cognitive processes has emphasized the phenomena of immersion and virtual self-representation. Immersion has been studied within the context of theories of 'Grounded Cognition' (Barsalou, 2008). The basic notion is that in

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**Fig. 1** University of Kentucky's island in SL

order to comprehend the complexity of cognition, one must avoid the traditional stratagem of isolating cognitive processes to a centralized model of mind, presumably located in one part of the body; i.e., the brain (Barsalou, 2008; Lakoff & Johnson, 1999; Wilson, 2002). The most relevant alternative of grounded cognition for VWs is the concept of *extended cognition*. This concept is used to explain how individuals relate to their avatars.

Noë's (2009) discussion of an experiment reported by Botvinick and Cohen (1998) frames the issue clearly. As depicted in Fig. 1, a participant sits with one hand out of view while looking at a rubber hand. An experimenter strokes the rubber hand with a brush while another experimenter synchronously brushes the participant's real hand. The provocative phenomenon is that the participant reports the sensation of being touched by the brush at the rubber hand; sensory awareness of our own body can extend to an object in the environment (Fig. 2).

In a similar manner, it is possible to extend the phenomenal experience of self to one's avatar, which is the basis of the VW principle of *embodiment*. According to Activity Theory, by embodying one's avatar and participating in mediated activities within the community of other VW users, one can extend their sense of identity to include their virtual self, *presence*, and others surrounding them, *co-presence* (Mennecke, Triplett, Hassall, Conde, & Heer, 2011). The extended sense of self results in immersion.

*Immersion* in a VW changes the perception of not only avatars, but also the VW itself. Virtual spaces have meaning, just like real-world places, and are experienced as representations of both physical space and social space (Gillen, Ferguson, Peachey, & Twining, 2012). The theoretically interesting implication is that features of virtual space create perceptual associations that generate a sense of place-presence. When a place has presence, the space becomes a context in which activities or events happen (Canter, 1977; Gustafson, 2001). Goel, Johnson, Junglas, and Ives (2013) attribute the popularity of VWs to the social prowess of

**Fig. 2** Illustration of rubber hand experiment. Kitagawa, N. (2013). "The rubber hand illusion." Reprinted from "Link between Hearing and Bodily Sensations" by N. Kitagawa, 2013, *NTT Technical Review, 11*(12). Copyright 2014 by The Telecommunications Association. Reprinted with permission

interactions that take place within virtual spaces. The Spatial Model of Interaction posits that a virtual environment generates cues fundamental to the interactions that occur within it (Benford & Fahlen, 1993). According to Awareness-Attention Theory, these cues lead to interactions that evoke attention and cause the user to internalize the interactions (Davenport & Beck, 2001). In other words, VWs provide backdrops that promote interactions that stick with us. Finally, Social Presence Theory suggests that different communication media vary in their individual capacity for transferring communication cues from the real world to the digital environment (Short, Williams, & Christie, 1976). The theoretical implication here is that the capacity of the technology we use will change the degree of connectivity we feel and our ability to express ourselves online.

Another theoretically rich aspect of VW psychology involves parallels and deviations between VW and real world behaviors. When a behavior in a VW is consistent with behavior in the real world, it is said to *map* onto the real world. Mapped behaviors can be produced in a virtual rendering of a real world situation and studied there to inform us about how they might organically occur within the real world (Williams, 2010). The flexibility and creative capabilities within VW technology empowers behavior researchers to take advantage of mapping by putting participants in procedures that might be risky or uncomfortable in real life.

It is useful to mention here another theoretical perspective pertinent to understanding VW psychology: Evolutionary Psychology. Although not pervasive in the VW literature, evolutionary psychology offers an important framework for thinking about psychological implications of digital simulations. This approach draws on Darwin's theory of natural selection (Darwin, 1859). The core assumption is that the architecture of the mind, both software and hardware, reflects evolutionary design. Most design features of the mind were laid down well before culture and technology emerged. The critical point is that the basic cognitive functions for which the mind was designed continue to constrain and influence the ways in which humans now apply their minds (Cosmides & Tooby, 2013). By implication, the verisimilitude of representations of real world affordances in a virtual world will impact VW psychology. Especially important is the level of realism associated with virtual objects and landscapes as well as facial and bodily signals of avatars.

A second implication of Evolutionary Psychology is that users enter a virtual environment prepared to react to VW stimuli as they would real world stimuli. For example, Kwan Min (2004) applies the evolutionary psychology perspective to explain presence. The natural preference when perceiving incoming stimuli is to accept the information rather than reject it, which confers survival value by inducing prompt reactions to our surroundings. Applied to VWs, we naturally accept digital representations of people, environments, and objects as if they were 'real.' Consequently, social reasoning applied to people in the real world is automatically extended to VWs.

In turning to social processes, research with VWs has been motivated by both general and specific theoretical questions. The former entails examination of the extent to which social phenomena found in the real world appear in VWs. For example, we will later describe studies that report VW replications of social influence, blind obedience, prejudice, bystander intervention, and nonverbal social norms. Specific theoretical interest in VW social processes has concentrated on phenomena unique to VWs. For example, the concepts of presence and co-presence derive from the mere existence of VWs as spaces that we engage in via technological interfaces distinct from the real world. Users within a VW can and do, under the right conditions, feel present in virtual spaces.

The concept of presence has been interpreted within the context of Embodied Social Presence theory (ESP). This theory describes the 'flow' experienced when users pursue goal-directed activities in a state in which people are more sensitive to communication. An avatar becomes a communication tool through which individuals manipulate and decode verbal and nonverbal cues more effectively because of embodied social presence (Mennecke et al., 2011). The implication here is that 'my avatar' is more than a particular collection of pixels that may resemble me; in the eyes of other VW users, it is a representation of the real me located in a real world.

## 3 Review of Findings

### *3.1 Cognitive Processes*

The idea of extended cognition leads to the question of whether users come to regard their avatar as a virtual expression of their real self. This question has been a major focus of VW psychology focused on the sense of self in immersive virtual environments. For example, Bailenson, Blascovich, and Guadagno (2008) explored the question of self in the co-presence of other avatars. Each participant was placed in a virtual room with an avatar whose appearance was similar to either himself/

herself or a stranger. The participants demonstrated greater intimacy with virtual selves than virtual others. They maintained less distance, showed a greater willingness to engage in embarrassing behaviors, and expressed greater attractiveness and liking for avatars similar to their real selves than for avatars similar to others. The authors discuss these findings in terms of the idea that individuals experience more intimacy with similar avatars because they can be perceived as virtual representations of themselves.

Another approach to the study of self in virtual settings is to focus on choices participants make while customizing the physical appearance of their avatars. Immersing in one's avatar is an activity where participants strive to satisfy identity needs from their real world lives. They do so by either developing a representation of a desired real world appearance, a reflection of their real world self, or a wholly different identity. Neustaedter and Fedorovskaya (2009) found that VW users shape their avatars to represent their self-concept in several different ways: *Realistics* represent their real world appearance; *Ideals* strive for better versions of their real self; *Fantasies* seek unrealistic appearances, and *Roleplayers* adopt appearances of fictitious characters.

The customization of avatar appearance not only supplements real world identity, but it can also impact the users' experiences and behaviors within a VW. You and Sundar (2013) found that customization of avatars heightens embodied perception of a virtual environment. Participants who customized their own avatars reported the perceived inclination of virtual hills as higher than participants who were assigned avatars. Yee (2014) has argued that manipulations of appearance and behavior in avatars we embody or interact with take advantage of phenomena from the real world to influence the virtual experience. As an example, using more attractive or taller avatars can cause more aggressive, extroverted, or confident behavior. Watching the behavior of avatars that look similar to us can cause imitation or conformity. Importantly, the impact of the immersive experience is not restricted to time spent in a VW. Roleplaying real life situations in VWs can lead to greater conscientiousness in decision-making in real life (Yee, 2014).

Perhaps the most provocative issue pertaining to the concept of self in VWs is the Proteus Effect. Several studies have shown that we conform our VW behavior to our perceptions of our VW appearances. For example, two studies by Yee and Bailenson (2007) show that changing physical attributes of avatars can produce greater confidence regardless of the physical appearances of participants in real life. Participants who adopted more attractive avatars disclosed more information and maintained less interpersonal distance with confederates than participants with less attractive avatars. Similarly, participants with taller avatars negotiated more aggressively than participants with shorter avatars. The Proteus Effect can even increase sexual self-objectification in women. Fox, Bailenson, and Tricase (2013) found that women who embodied sexualized avatars reported thinking more about their bodies than those with non-sexualized appearances and expressed rape myth acceptance more often.

Research on the Proteus Effect has also demonstrated that events in a VW can have a direct impact on behavior upon returning to the real world. Follow-up studies on the influence of controlling taller or more attractive avatars found that the effect persisted in similar circumstances in the real world. For example, participants negotiated more aggressively in face-to-face situations after using a tall avatar. Those who controlled attractive avatars selected more attractive partners for blind dates from online dating profiles than those who embodied less attractive avatars (Yee, 2014).

The area of romantic relationships blurs the distinction between what goes on in the real world and the VW. The anonymity of VWs and the possibilities of deception can deter users from pursuing offline relationships with other online users. Nonetheless, 30 % of online gamers develop romantic feelings for others, and around 10 % of them physically date someone they connect with online. Out of 115 survey participants who had physically dated someone from an online game, 60 % believed they would not have dated that person had they first met face-to-face (Yee, 2014).

Beyond the cognition of self, other basic cognitive effects have been shown to extend to VWs as well. For example, Segovia and Bailenson (2009) discovered a false memory effect in an immersive virtual environment. Children were told two stories of an event that supposedly happened to them and were then shown a virtual simulation. The children were then asked if they remembered the event. Immersive virtual environment technology was effective in prompting false memories, particularly when simulations included virtual representations of the participant.

A final area of research associated with basic cognitive functions pertains to personality. Behavioral and linguistic practices original to VWs create novel ways for personality traits to manifest. For example, a number of studies have examined whether there are specific VW behaviors or communication patterns that correlate with the Big Five personality factors. As an example, Yee, Harris, Jabon, and Bailenson (2011) found a correlation between low emotional stability and more frequent log-ins to the virtual world SL with shorter durations of in-world time.

### *3.2 Social Processes*

Social processes in VWs have been approached from two main perspectives. First, there has been considerable interest in real world social phenomena that also appear in VW settings. To date a number of such phenomena have been discovered. Two examples of this trend include the classic psychological phenomena of social influence (Asch, 1951) and blind obedience (Milgram, 1963). Using a task and general methodology similar to the initial Asch studies and as depicted in Fig. 3, Rayburn-Reeves, Wu, Wilson, Kraemer, and Kraemer (2013) found a relatively robust social influence effect tested in SL. Participants inaccurately judged the length of a line in conforming to judgments of three confederate avatars.

Similarly, Slater et al. (2006) replicated the blind obedience effect. Participants were asked to test a virtual human for word associations, administering electric shocks for incorrect answers as occurred in the original real world study. Despite

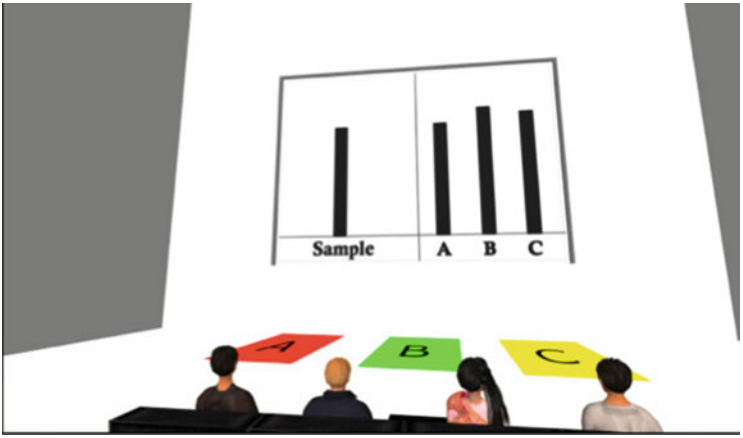


**Fig. 3** A VW version of the Asch procedure used to study social influence. Kraemer, B. (2014). "Snapshot_013." Retrieved September 28, 2014 from: https://www.flickr.com/photos/alice_burgess/15320217816/in/set-72157647570093779. Reprinted with permission

knowing the events were not real, the avatar's responses to the shocks evoked subjective, behavioral, and physiological reactions from the participants comparable to the real world study.

Another social phenomenon found to manifest in both real and virtual settings involves the role of nonverbal social cues. In an observational study in Second Life (SL), Yee, Bailenson, Urbanek, Chang, and Merget (2007) demonstrated that nonverbal cues, particularly interpersonal distance and eye gaze, transfer into dyadic interactions between avatars. Likewise, it has been shown that perception of avatars is influenced by prejudice in ways similar to real world behavior. Dotsch and Wigboldus (2008) found that native Dutch participants increased personal distance with avatars with Moroccan features compared to Caucasian avatars and experienced increased skin conductance levels in their real world physical bodies.

Research has demonstrated that factors which determine when or if bystanders will intervene to aid another in the real world (Peter et al., 1972), or bystander effects, have been replicated in VWs. King, Warren, and Palmer (2008) found that most SL users defer to assumed authority and rationalize inaction to delinquent or obscene behaviors. When a deviant SL user made offensive behaviors of a sexual nature, most bystanders ignored him. When the behavior progressed to persistent harassment of individuals, most onlookers made comments about how he would be removed from the world by authorities or the developers, but none made the move to report his character.

Another question of interest in the study of social processes in VWs pertains to communication. As an example, Pertaub, Slater, and Barker (2002) had participants give 5-min presentations to audiences of male avatars who exhibited positive, negative, or neutral behaviors. Those who presented before the negative audience demonstrated more anxiety than those who spoke before the other two audiences, and they reported levels of confidence lower than their baselines. In addition, many participants described the negative audience as being the most realistic. In general, the way the avatar audience reacted had an impact on how participants perceived them.

In an investigation of interactions among avatars, Bailenson, Yee, Merget, and Schroeder (2006) conducted a study examining disclosure and self-reported co-presence. Participants interacted in dyads via three different communication media varying in form and behavioral realism. *Form realism* is a measure of the similarity in appearance between the avatar and the person behind it, while *behavioral realism* corresponds to how accurately the actions of the avatar depict the user (hand gestures, voice and tone, or walking). People disclose more information when their avatar is low on behavioral realism and emote more generously when their avatar is low on form realism. In general, people tend to compensate for the physical or body-related communication cues that are not present in the simulation with their online behaviors.

### *3.3 User Characteristics*

The psychology of VWs has also been studied in terms of how characteristics of users shape virtual behavior. For example, survey data of players in the popular online game World of Warcraft (WoW) indicate evidence of relationships between personality traits and game behavior. Players high in extraversion, agreeableness, intellect, and tolerance report playing for achievement and completion of in-game objectives, cooperate more, and are more prone to pro-social behaviors. Those high in dominance, leadership, masculinity, and narcissism are drawn to the game for competition, spend more time fighting, and express more confidence in their in-game actions (Mosley, 2010). The company behind WoW, Blizzard Entertainment, created a website called the Armory, which freely distributes a comprehensive profile for every active character currently playing in-world. In a study of 1040 WoW players, players who rate high in extraversion are shown to prefer group activities and are more likely to participate in large dungeon raids, whereas those low on extraversion prefer solo activities such as cooking or completing quests. Those with more openness to experience have more characters, play on more servers, and spend more time actively exploring the game world. Players low on openness to experience stick to simple activities like combat (Yee, 2014).

Gender is another important variable that has garnered attention in VW research. Males and females interact differently through their avatars and perceive others differently based on their avatar's gender. Yee et al. (2007) found that males maintain greater personal distance between their avatars than females. In general, perception of gender has become an important factor in gaming culture within VWs. As a result, the practice of assuming avatars opposite to one's real world gender is not unusual. Evidence indicates that gender identity deception in avatar appearance and disclosed 'real' gender impacts the likelihood of helping behaviors in VWs. Waddell (2012) conducted a field study of 1221 WoW users and found that when an avatar with an attractive appearance claimed to be female in the real world, they were more likely to receive help requested from other users. Interestingly, males who use cross-gender avatars are not penalized or discriminated against by their fellow users, whereas females wearing cross-gender avatars are perceived more negatively.

## 3.4 Applications of Virtual Worlds

It is not surprising that researchers have begun to appreciate the value of virtual psychology to the study of applied problems. Education is one of those important areas. The study of learning affords an especially rich research opportunity to exploit VW technology. At the most basic level, learning within VWs is naturally required in order to operate the technological interface associated with a particular VW. Engagement in any activity within a VW entails exploration and discovery, which itself affords an opportunity to practice using the interface. Many educators and educational institutions have taken advantage of the virtues of VWs by creating their own virtual learning spaces.

VWs provide effective platforms with which to create a sense of community through various pedagogies. Five features of virtual classrooms of the type depicted in Fig. 4 contribute to their effectiveness for distance learning: collaborative activity, co-location of shared virtual space, the capacity for spontaneous interaction, peripheral awareness, and the potential for non-verbal communication (Redfern & Galway, 2002). The flexibility of virtual environments supports the creation of collaborative and interactive zones, campuses for student community, and lecture rooms to produce virtual learning institutions that can meet the social, academic, and collaborative needs of students.

A very creative use of VWs in education involves medical training. Costs, ethical issues, and availability of patients have led to the use of virtual learning (Spooner, Cregan, & Khandra, 2011). As an example, Richardson, Hazzard, Challman, Morgenstein, and Brueckner (2011) created the SL virtual anatomy lab illustrated in Fig. 5 in and demonstrated that it could be used successfully to promote problem-based learning.

Another interesting example of VW education is Virtual Ability Island in SL, created by Zielke, Roome, and Krueger (2009) to teach VW interface skills to people with disabilities. Modeled as a tropical island, users are able to practice all the necessary skills they need to learn in a fun, stress-free setting by engaging in activities such as dancing under lanterns. The island is designed to allow users to pace themselves and self-direct their own learning.

An especially valuable opportunity to use VWs for educational purposes entails learning of foreign languages, particularly for the student anxious about speaking a new language for the first time. Immersive online spaces can lower inhibition and social anxiety (Roed, 2003). The development and implementation of the Tactical


**Fig. 4** Distance Education in SL. Kraemer, B. (2009). "Educause SL session." Retrieved September 28, 2014 from: https://www.flickr.com/photos/alice_burgess/4075362649/in/set-72157647570093779. Reprinted with permission

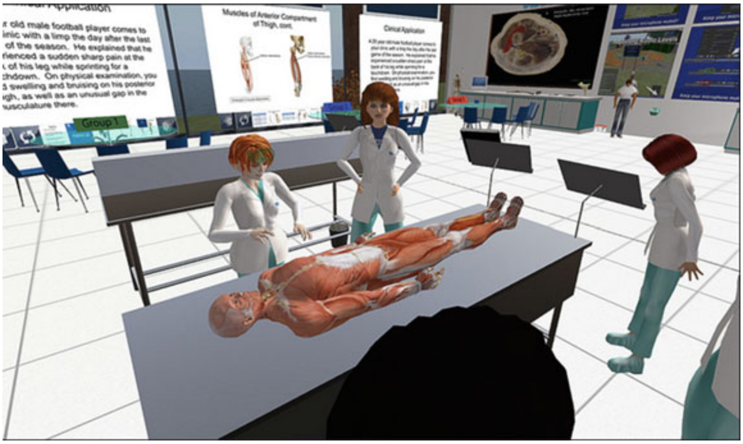

**Fig. 5** VW education: an Anatomy Lab in SL. Kraemer, B. (2010). "Anatomy lab, body avatar 2." Retrieved September 28, 2014 from https://www.flickr.com/photos/alice_burgess/5242203918/in/set-72157647570093779/. Reprinted with permission

Language Training System successfully utilizes a virtual environment to promote foreign language learning among U.S military personnel (Johnson et al., 2004). Learners practice interactions with virtual native speakers in a mission-based game. Similarly, Zheng, Young, Brewer, and Wagner (2009) found that engaging in the game-like virtual world Quest Atlantis led to higher ratings of attitudes and self-efficacy toward English use and in nonnative English speakers. Students reported greater willingness to communicate and in English through Quest Atlantis compared to learning English in the classroom.

Beyond education, there has also been a great deal of interest in using VWs to study the learning process. For example, Good, Howland, and Thackray (2008) concentrated on problem-based learning that was distributed across virtual and real worlds. Using SL, they paired teams of students with a real world client to investigate a particular issue and asked them to build an interactive learning experience within SL. Teams were initially inactive and began constructing traditional classrooms. Over time, as students gained confidence in building within SL, a number of groups branched off into more novel directions.

In another study, Gillen et al. (2012) challenged teenage participants to learn how to pilot sailboats, design how to conduct sailboat races, and then compete against each other. Logs of messages between participants during sailboat races revealed when learning occurred. For instance, students had to determine the best way to communicate the start of a sailboat race. Through trial and error, they settled on using visual signals. Learning in VWs results from interactions with objects in a VW as well as from relationships formed with other users. To that end, Gillen et al. (2012) discovered several principles of collaborative learning in a VW: Learning is fostered by encouraging users to ask questions, willingness of members to help others, appreciation of the achievements of objectives, participation in all communicative domains, and the use of humor.

Another applied area in which VWs are being utilized involves mental health. Whether it is to help conquer fears, reduce anxiety, or address other therapy needs, virtual environments can provide an effective therapeutic strategy to meet social or physical needs unmet in the real world. EMMA's World was created with specific elements to accommodate the needs and abilities of users. It provides a special place where participants can safely express their emotions (Botella, Osma, & Palacios, 2008). EMMA's World is designed to reflect emotions and aid the user in emotional processing with conditions such as PTSD or complicated grief. This VW has been used to provide a space to complete tasks avoided in the real world, such as visiting a cemetery. VWs have also been used to explore the experience of schizophrenia (Yellowlees & Cook, 2006). The Virtual Hallucinations building in SL was created at the University of California-Davis to replicate auditory and visual hallucinations of schizophrenic patients. The simulation is used to provide treatment and to train therapists.

## 4 Future Directions

Messinger, Stroulia, and Lyons (2008) categorized the dimensions of VW use and development into three areas: (1) applications for business, ecommerce, and education; (2) development of new technology and interfaces for VWs; and (3) new research topics for social, business, and computing sciences. VWs may be applied to new purposes, designed and targeted to new populations, utilized with new profit models, or offered through new interfaces (such as smartphones). All three areas will continue to grow as virtual reality technologies become more accessible and more commonplace. Yee (2014) describes VW applications as those that replicate reality (human behavior research and economic applications), influence reality (education and therapy), and reimagine reality by creating bodies and worlds without constraints (gaming and entertainment). VWs can simulate, supplement, and challenge the real world. Virtual reality technology not only augments the real world, it also provides space to generate and explore novel ideas.

In contemplating the future of VWs, a major variable will be the technology itself. The development of culture and society within a VW and the subsequent experience of users within it are shaped by the limits and affordances set by the software and hardware. For example, the amount of user customization allotted to avatar appearance and the capabilities for users to engage in activities within the VW through manipulation of their avatars determine the peak degree of embodiment and engagement that can be achieved through immersion in a VW (Yee, 2014). As digital technologies evolve, there will be even better opportunities to simulate the affordances available in the real world. Devices for creating stimulation for touch and olfactory senses are already being used in combination with virtual reality technology (Blascovich & Bailenson, 2011). It is only a matter of time before virtual reality can be experienced with all of our senses. A related possibility is the emergence of capacities to more accurately represent stimuli that serve as fundamental affordances in the real world. For example, digital innovations that produce more realistic simulation of facial muscles, pupil dilation, and eyebrow movement will profoundly upgrade the richness of expressed emotionality of avatars.

These kinds of changes will motivate continued research on VW psychology. The implicit assumption is that as VWs become more realistic, differences between virtual and real behavior will diminish toward psychological equivalence. This assumption, however, deserves empirical validation. It may be that behavioral equivalence can be realized with lower levels of realism than is often assumed. It may also be the case that there will always be some boundary separating the virtual from the real that has psychological relevance.

As a tool, VWs are one of the most efficient platforms for human behavior research. VWs can provide large amounts of data on huge populations of individual users at any given time (Loomis, Blascovich, & Beall, 1999). Additionally, VW experiences are entirely removed from physical bodies. Mapping, as mentioned earlier in this chapter, is an approach to behavioral research that takes advantage of the creation of VWs to answer questions that cannot be posed in the real world without putting real lives at risk such as the consequences of major social and economic policy changes. Learning about behaviors for which mapping can be established and validated in VWs can provide scientists with a practical, safe, and effective venue to study such topics (Williams, 2010).

Another valuable line of research is the investigation of how transitions in VW participation levels will change as user skills increase from growing familiarity with the technologies. For example, the question of whether childhood experience with VW tools affects VW psychology is important to all applied aspects of VWs. How and in which ways virtual experience changes real world psychology is especially pertinent to the effort to integrate VWs into real life in ways that are safe, beneficial, and productive. Consequently, it is reasonable to anticipate expanded research on such phenomena as the Proteus Effect. In general, technological augmentations always have a dual impact: people do new things or do them differently while no longer doing old things. Future research therefore will not only concentrate on specific elements of virtual-real world connections, but will also expand investigations of molar effects of virtual experience (e.g. how time spent in VWs influences real world behavior).

Finally, a question that will grow in importance is how VWs are integrated into the entire arsenal of digital communications and social media that will become available. Especially as technologies establish mobile contact with VWs, new fertile research opportunities will emerge. Ultimately, however, the question of whether real world lives are regarded as being more or less meaningful as a function of VW experiences becomes critical, which is perhaps the essential question to ask about VW psychology.

## References


Asch, S. E. (1951). Effects of group pressure upon the modification and distortion of judgments. In H. Guetzkow (Ed.), *Groups, leadership, and men* (pp. 222–236). Pittsburgh: Carnegie Press.

Bailenson, J. N., Blascovich, J., & Guadagno, R. E. (2008). Self-representations in virtual environments. *Journal of Applied Social Psychology, 38*(11), 2673–2690.

Bailenson, J. N., Yee, N., Merget, D., & Schroeder, R. (2006). The effect of behavioral realism and form realism of real-time avatar faces in verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction. *Presence, 15*(4), 359–372.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–645.

Benford, S. D., & Fahlen, L. E. (1993). A spatial model of interaction in large virtual environments. In *Proceedings of the third European conference on CSCW IEC-SCW '93*, Milano, Italy.

Blascovich, J., & Bailenson, J. (2011). *Infinite reality: Avatars, eternal life, new worlds, and the dawn of the virtual revolution*. New York, NY: William Morrow & Co.

Botella, C., Osma, J., & Palacios, A. G. (2008). Treatment of complicated grief using virtual reality: A case report. *Death Studies, 32*, 674–692.

Botvinick, M., & Cohen, J. (1998). Rubber hands' feel' touch that eyes see. *Nature, 391*(6669), 756.

Canter, D. (1977). *The psychology of place*. London: Architectural Press.

Cosmides, L., & Tooby, J. (2013). Evolutionary psychology: New perspectives on cognition and motivation. *Annual Review of Psychology, 64*, 201–229.

Darwin, C. (1859). *On the origins of species by means of natural selection*. London: Murray.

Davenport, T., & Beck, D. (2001). *The attention economy: Understanding the new currency of business*. Boston, MA: Harvard Business School Press.

Dotsch, R., & Wigboldus, D. H. J. (2008). Virtual prejudice. *Journal of Experimental Social Psychology, 44*, 1194–1198.

Fox, J., Bailenson, J. N., & Tricase, L. (2013). The embodiment of sexualized virtual selves: The Proteus effect and experiences of self-objectification via avatars. *Computers in Human Behavior, 29*, 930–938.

Gillen, J., Ferguson, R., Peachey, A., & Twining, P. (2012). Distributed cognition in a virtual world. *Language and Education, 26*(2), 151–167.

Goel, L., Johnson, N., Junglas, I., & Ives, B. (2013). Predicting users' return to virtual worlds: A social perspective. *Information Systems Journal, 23*, 35–63.

Good, J., Howland, K., & Thackray, L. (2008). Problem-based learning spanning real and virtual words: A case study in Second Life. *Association for Learning Technology Journal, 16*(3), 163–172.

Gustafson, P. (2001). Meanings of place: Everyday experience and theoretical conceptualizations. *Journal of Environmental Psychology, 21*(1), 5–16.

Johnson, W. L., Marsella, S., Mote, N., Viljhálmsson, H., Narayanan, S., & Choi, S. (2004). Tactical language training system: Supporting the rapid acquisition of foreign language and cultural skills. In *InSTIL/ICALL symposium 2004*.

King, T. J., Warren, I., & Palmer, D. (2008, January). Would Kitty Genovese have been murdered in Second Life? Researching the "bystander effect" using online technologies. In *TASA 2008: Re-imagining sociology: The annual conference of The Australian Sociological Association* (pp. 1–23).

Kwan Min, L. (2004). Why presence occurs: Evolutionary psychology, media equation, and presence. *Presence: Teleoperators and Virtual Environments, 13*(4), 494–505. doi:10.1162/1054746041944830.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. New York, NY: Basic Books.

Loomis, J. M., Blascovich, J. J., & Beall, A. C. (1999). Immersive virtual environment technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, and Computers, 31*(4), 557–564.

Mennecke, B. E., Triplett, J. L., Hassall, L. M., Conde, Z. J., & Heer, R. (2011). An examination of a theory of embodied social presence in virtual worlds. *Decision Sciences, 42*(2), 413–450.

Messinger, P. R., Stroulia, E., & Lyons, K. (2008). A typology of virtual worlds: Historical overview and future directions. *Journal for Virtual Worlds Research, 1*(1), 1–18.

Milgram, S. (1963). Behavioral study of obedience. *Journal of Abnormal and Social Psychology, 67*, 371–378.

Mosley, I. D. (2010). Personality and character selection in World of Warcraft. *McNair Scholars Research Journal, 6*(1), 12.

Neustaedter, C., & Fedorovskaya, E. (2009). Presenting identity in a virtual world through avatar appearances. In *Proceedings of graphics interface 2009* (pp. 183–190).

Noë, A. (2009). *Out of our heads: Why you are not your brain, and other lessons from the biology of consciousness*. New York, NY: Macmillan.

Pertaub, D., Slater, M., & Barker, C. (2002). An experiment on public speaking anxiety in response to three different types of virtual audience. *Presence: Teleoperators and Virtual Environments, 11*(1), 68–78.

Peter, L., Diane, L., Marc, A., David, F., Betty, F., & McGrath, J. E. (1972). Bystander effect in a demand-without-threat situation. *Journal of Personality and Social Psychology, 24*(2), 166.

Rayburn-Reeves, R., Wu, J., Wilson, S., Kraemer, B., & Kraemer, P. (2013). Do as we do, not as you think: The effect of group influence on individual choices in a virtual environment. *Journal of Virtual Worlds Research, 6*(1), 1–11.

Redfern, S., & Galway, N. (2002). Collaborative virtual environments to support communication and community in internet-based distance education. *Journal of Information Technology Education: Research, 1*(1), 201–211.

Richardson, A., Hazzard, M., Challman, S. D., Morgenstein, A. M., & Brueckner, J. K. (2011). A "Second Life" for gross anatomy: Applications for multiuser virtual environments in teaching the anatomical sciences. *Anatomical Sciences Education, 4*(1), 39–43.

Roed, J. (2003). Language learner behaviour in a virtual environment. *Computer Assisted Language Learning, 16*(2-3), 155–172.

Segovia, K. Y., & Bailenson, J. N. (2009). Virtually true: Children's acquisition of false memories in virtual reality. *Media Psychology, 12*, 371–393.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: Wiley.

Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., et al. (2006). A virtual reprise of the Stanley Milgram obedience experiments. *PLoS One, 1*(1), e39.

Spooner, N. A., Cregan, P. C., & Khandra, M (2011). Second life for medical education. *eLearn Magazine*. Retrieved from http://elearnmag.acm.org/featured.cfm?aid=2035934

Waddell, T. F. (2012). *It's not easy trying to be one of the guys: The effect of avatar attractiveness, avatar gender, and purported user gender on the success of help-seeking requests in an online game*. Unpublished master's thesis, Virginia Polytechnic Institute and State University, Virginia, USA. Retrieved from http://scholar.lib.vt.edu/theses/available/etd05142012184457/unrestricted/Waddell_Thomas_F_D_2012.pdf

Williams, D. (2010). The mapping principle, and a research framework for virtual worlds. *Communication Theory, 20*, 451–470.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review, 9*(4), 625–636.

Yee, N. (2014). *The Proteus paradox: How online games and virtual worlds change us-and how they don't*. New Haven, CT: Yale University Press.

Yee, N., & Bailenson, J. N. (2007). The Proteus effect: Self transformations in virtual reality. *Human Communication Research, 33*, 271–290.

Yee, N., Bailenson, J. N., Urbanek, M., Chang, F., & Merget, D. (2007). The unbearable likeness of being digital: The Persistence of nonverbal social norms in online virtual environments. *CyberPsychology and Behavior, 10*(1), 115–121.

Yee, N., Harris, H., Jabon, M., & Bailenson, J. N. (2011). The expression of personality in virtual worlds. *Social Psychological and Personality Science, 2*(1), 5–12.

Yellowlees, P. M., & Cook, J. N. (2006). Education about hallucinations using an internet virtual reality system: A qualitative survey. *Academic Psychiatry, 30*(6), 534–539.

You, S., & Sundar, S. S. (2013). I feel for my avatar: Embodied perception in VEs. In *Proceedings of the 2013 Annual Conference on Human Factors In Computing Systems (CHI'13)* (pp. 3135–3138).

Zheng, D., Young, M. F., Brewer, R. A., & Wagner, M. (2009). Attitude and self-efficacy change: English language learning in virtual worlds. *CALICO Journal, 27*(1), 205–231.

Zielke, M. A., Roome, T., & Krueger, A. B. (2009). A pedagogical model for virtual world residents: A case study of the virtual ability Second Life Island. *Journal for Virtual Worlds Research*, *2*(1).

# Virtual Worlds for Energy: A Topical Review

**Nick V. Flor and Olga Lavrova**

## 1 Introduction

Fossil fuels are dwindling (see box), and people must learn how to live in a world less dependent on fossil fuels. This requires people developing energy management skills, which include: understanding the main and highest kinds of daily electrical loads; planning for purchasing and using sustainable and renewable energy sources; and planning to purchase products powered by renewable energy.

> In the United States alone, given the current supplies of oil and natural gas, and the current consumption rates of these fossil fuels, there are only 24 years left of oil and 92 years left of natural gas (see Table 1; EIA, 2013; Whitney, Behrens, & Glover, 2010). These stats are alarming, particularly since the United States has the largest supply of fossil fuel remaining in the world. Thus, energy is a major issue for the not-so-distant future.

Virtual worlds are an ideal environment for people to learn energy management skills because they provide solutions to many of the problems that prevent the typical person from developing these skills.

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**Table 1** Oil and natural gas remaining

| Type | Technically recoverable + Reserves remaining | Yearly rate of consumption | Years left |
|---|---|---|---|
| Oil | 162.9 BBO (Billion Barrels of Oil) | 6.87 BBO | 24 |
| Natural gas | 2203 Tcf (Trillion cubic feet) | 24 Tcf | 92 |

One major problem is that energy is difficult to imagine and quantify over time for most people—who only pay attention to their energy usage when they receive their monthly electricity bill. However, a virtual world can be programmed to persistently visualize energy usage and energy patterns for users, and to allow users to drill down and discover how specific appliances contribute to energy usage.

Another major problem with people learning energy management skills is that existing renewable energy sources like solar and wind are too expensive for the average consumer to purchase. Moreover, the most promising renewable energy sources—like energy harvesters that simultaneously convert solar, radio waves, heat, and movement into electricity—are still in the research and development stages. Consumers also view these technologies as risky because it is unclear how they will perform in suboptimal conditions, like cloudy or windless days.

However, with a virtual world, both younger and older generations of people can experiment with purchasing either existing or experimental renewable energy sources that today may be too costly or impossible to acquire (see Fig. 1). They can also experiment with managing these energy sources under a variety of suboptimal environmental conditions. While the costs and consequences may be virtual, the learning of energy management skills is both actual and applicable.

This chapter will provide a topical review of how 3D3C virtual worlds are currently being used to train people on energy-related issues, and to prepare people for a future where fossil fuels play a more limited role than they do today. The review is design science oriented (March & Smith, 1995; Simon, 1969), with a focus on providing results to researchers at the goal and mechanism level, which they can then use to design their own systems, or use for iterative improvement on an existing system. This chapter is organized as follows. First, we describe the methodology used to find research articles and virtual worlds specific to energy management and conservation; we also describe the framework for writing up our findings. Next, we do a topical review of energy-themed virtual worlds with an emphasis on 2.5D serious games. We choose to review serious games because there are no fully-developed, energy-themed 3D3C virtual worlds as defined by Sivan (2008), but nevertheless the goals and mechanisms in these games are transferrable and can be implemented in 3D and they are a step in the right direction. Lastly, we summarize our findings and end with a discussion of future design research challenges.


**Fig. 1** An example virtual solar home (SHADE) developed by the authors. In a virtual world, players can experiment with renewable energy technologies, like solar, that would otherwise be too costly to purchase or with technologies that are in experimental stages

## 2 Methodology

We used two phases to conduct the research in this paper. The first was to search for virtual energy worlds, and the second was to report our findings.

Our original intent was to review research on energy use in virtual worlds. However, finding research articles on energy uses of virtual worlds was non-trivial and unproductive for several reasons. First, energy is not a common application domain for virtual worlds. Second, there are many terms that researchers use as synonymous with “virtual worlds” including multi-user virtual environments (MUVES), serious games, or even video games to name just a few. Lastly, searching over “energy” will return articles only tangentially related to energy as an application domain for virtual worlds. Examples of the latter include articles about the physical energy that a person expends interacting with a virtual world, or articles about the electricity that a computer consumes while a person explores a virtual world. To trim down the number of tangential articles related to energy uses of virtual worlds, we also searched on the subject fields: energy conservation, energy management, and energy consumption.

Specifically, we searched through the University of New Mexico’s online library catalog: library.unm.edu, using multiple queries over the key words keywords *energy*, *virtual worlds*, *serious games*, or *video games*, and over the subjects: *energy conservation*, *energy management*, and *energy consumption*. The search was conducted over the following databases: Academic Search Complete, Art Index, ArticleFirst, Business Source Complete, Education Abstracts, ERIC, JSTOR Arts & Sciences Collection I-XII, MLA International Bibliography, Project Muse, PsycARTICLES, and WorldCat.org. We then read the abstracts, in order to further narrow down the list, and read through and reviewed those articles where users had to specifically manage energy in the virtual world.

There results were several articles on energy-themed serious games, and no research articles on energy-themed 3D3C virtual worlds. These serious games were 2.5D—they displayed 3D graphics, but player movements were limited to 2-dimensions. Nevertheless, energy is an important global issue, and the serious game articles described learning goals and learning mechanisms that could be implemented in 3D3C virtual worlds. We therefore decided to review energy-themed games with the aim of identifying these goals and mechanisms.

## *2.1 Finding Energy-Themed Virtual Worlds*

We consider 2.5D serious games as kinds of virtual worlds. To find energy-themed serious games qua virtual worlds, we used Google and searched for *energy serious games*. Whenever we inspected the results and found a website containing an energy-themed virtual world, we entered that URL into Google and then used the "Similar" tool to find similar websites. We also entered the URL into Alexa.com, which returned the search terms that other users had entered to find the website. Finally, we then entered those search terms back into Google to find more virtual worlds.

We discovered a number of city-level energy simulations, which were similar in goals and playability. We select two of these (*EnergyVille* and *PowerMatrix*) for review, as representative of these city-level simulations. We also found two unique energy-themed games, *2020 Energy* and *Power House*. The former combined energy and sustainability, and the latter used actual home energy data inside of the virtual world. We will review these games in addition to our own energy-themed virtual world.

## *2.2 Reviewing Energy-Themed Virtual Worlds*

Once the articles were selected and the virtual worlds found, we used Marr's three levels (Marr 1982) to organize our review. Briefly, Marr was a neuro-and cognitive scientist who specialized in visual processing. He argued that any information processing system must be understood at three levels in order to be fully understood: the computational theory level, the representation and algorithm level, and the hardware implementation level. A virtual world is an information processing system and so it can be analyzed using Marr's three levels.

Applied to virtual worlds, understanding a virtual world at the computational theory level means stating the goal(s) accomplished by the user interacting with the virtual world. An example of a goal is conserving energy. However, when people interact with tools to accomplish systemic goals like conserving energy, they may acquire knowledge over time such as learning energy efficient behaviors that apply to the real world. This cognitive *residua*, may or may not be planned by the designers, e.g., as part of a scaffolding strategy. Still, it is important at the computational theory level to describe both systemic goals, and the knowledge and skills potentially acquired by the user through interaction with the tool over time. We will use the term "*goal*" in place of "computational theory" in our review.

Understanding a virtual world at the representation and algorithm level, means characterizing the information that the user sees and the procedures that the user employs to manipulate the information in order to accomplish the goal. For example, in an energy virtual world whose goal is to conserve energy, users are given representations of electrical appliances. They conserve energy through a process—or algorithm—of inspecting each appliance and turning it off if it is on unnecessarily or, rescheduling the turning on of an appliance to a time of the day when electricity costs are lower, e.g., operating a clothes dryer in the night. We will use the term "*mechanism*" in place of "representation and algorithm" in our review.

Understanding a virtual world at the implementation level means specifying the form of the representations the user perceives and manipulates, as well as the specific actions a user must take to implement an algorithm. For example in an energy world that has representations of appliances, these representations can take the form of a word, e.g., toaster, a 2D picture, e.g., a cartoon toaster, or a realistic 3D model of a toaster. An appliance can have the words "on" or "off" superimposed over it to denote is state, or have a green or red hue to indicate its state. The algorithm of inspecting each appliance to determine if it is on unnecessarily can be accomplished by looking at a word list of appliances that are on, inspecting a 2D representation of a house with appliances on, or by having a user's avatar visit each room in a 3D house and looking at the colored outlines of appliances. To turn an appliance on and off can be accomplished by clicking on the appliance, tapping on the appliance, or even—if voice recognition tools are available—telling the virtual world to turn an appliance on or off.

The benefit of using Marr's three levels of analysis is that it allows us to review any energy-themed serious game, whether 3D or not, to identify mechanisms that may be beneficial if implemented in a 3D3C virtual world. Additionally, we will examine replay and promotion mechanisms.

## 3 A Topical Review of Five Energy-Themed Virtual Worlds

As mentioned, one of benefits of using Marr's three-levels of analysis is that it allows us to review energy-themed serious games, which do not have to be 3D3C virtual worlds, and to identify useful goals, along with the mechanisms used to accomplish those goals. These goals and mechanisms can then be implemented in a 3D3C virtual world. We first review our own virtual world for energy.

**Fig. 2** An avatar in a virtual world, depicting a neighborhood

## *3.1 Virtual Energy World*

The Virtual Energy World (www.virtualenergyworld.com, click "play" button) is a 3D interactive visualization developed entirely by art, business, and engineering undergraduate and graduate students as part of the National Science Foundation's Sustainable Energy Pathways Through Education and Technology (SEPTET) program at the University of New Mexico. The target audience for the virtual energy world is teenagers and households. The system uses the Unity3D engine, and all avatars and environmental figures were animated and modeled using the Autodesk Maya software package.

Similar to other 3D virtual worlds, after a user selects an avatar, he or she can enter the virtual world (see Fig. 2), and interact with objects in the environment.

The key object is the house. Users are assigned a house that they can enter by clicking on the door of their house (Fig. 3).

It is inside a user's home where an energy-themed virtual world starts to differ from other virtual worlds. Specifically, appliances in non-energy-themed virtual worlds are largely decorative and do not consume energy. In an energy-themed virtual world, appliances have states (see Fig. 4), and when they are on they can consume variable amounts of energy.

### 3.1.1 Goals

The virtual energy world is designed to be a continually evolving platform for instructing users on renewable and sustainable energy issues in a more immersive and interactive manner than current information sources. The instructional goal of the initial implementation is to help users understand the power requirements, or wattages, of various household appliances.

**Fig. 3** A common interaction, clicking on a house's door brings the avatar inside the house

**Fig. 4** In an energy-themed virtual world, appliances have states. In this example, off is denoted by a *red outline* and on by a *green outline*

#### 3.1.2 Learning Mechanisms

Users can learn about appliance power requirements in two modes. In free-form mode, users can wander around their homes, examine various appliance wattages, and switch appliances on and off. As each appliance is switched, the virtual world displays total power usage. In quest mode, the virtual world asks users to perform various actions on appliances, or to answer questions related to power requirements. In a classroom environment, teachers can create quests for their students either to instruct students on appliance power requirements or to test knowledge of appliance wattages.

#### 3.1.3 Replay and Promotion Mechanisms

The current version of the Virtual Energy World has no designed replay or promotion mechanisms, aside from the user trying to improve his or her score in the quests.

#### 3.1.4 Implementation

Users switch appliances on and off by either clicking or tapping on their visual representations. Appliance on/off state is denoted by a colored border, with green indicating "on" and red indicating "off." Users can reveal the wattages of

**Fig. 5** The coffee maker is “on” as denoted by the green outline, and the number 900 superimposed over it indicates that it is consuming 900 W of power. The 3100 W in the *upper-right* corner is the total wattage of the coffee maker, stove, and dishwasher

appliances by either hovering the mouse pointer over an appliance or tapping and holding an appliance. The virtual world will then superimpose the wattage over the appliance along with the total power used in the upper-right corner (see Fig. 5).

Virtual Energy World provides a minimum feature set for learning about power issues at the household level, in an immersive and interactive manner. A teacher could take this minimum virtual world, and augment it with quests where students learn about energy requirements of specific appliances, or the costs of running multiple appliances over time, or ways of conserving energy. But appliance power is just one of many energy issues that users can explore and learn about in virtual worlds. Next, we analyze four other energy-themed serious games to discover goals and mechanisms appropriate for a 3D3C virtual energy world.

## *3.2 2020 Energy*

2020 Energy (http://www.2020energy.eu/game) is an energy-themed serious game that targets 14–18 year old teenagers. It is implemented as a cross-platform app, playable over the web or on an iPhone. The game was funded by Intelligent Energy Europe, and was co-produced by UniverseScience, France TV Education, and Tralalere.

### 3.2.1 Goals

The instructional goal is to provide players knowledge about how to reduce their consumption of energy, how to increase energy efficiency, and how to choose the best renewable energies. What is unique about 2020 Energy is that users learn the


**Fig. 6** The sustainable development diagram used to provide feedback to players about the decisions they make in the game. The goal is to make a decision that is sustainable

benefits and costs of decisions at three different levels: individual, local, and global, and across three different concerns: environmental, social, and economic. The game goal is to make decisions that are sustainable, where a sustainable decision is defined as one that simultaneously benefits the environment, society, and the economy (see Fig. 6).

### 3.2.2 Learning Mechanisms

The user accomplishes the learning goals through mini-games. There are nine mini-games (refer to Fig. 7), categorized according to level (individual, local, global) and further categorized in terms of learning topic (energy savings, energy efficiency, renewable energy).

In each mini-game, a player must solve a real-world problem that involves energy and sustainability. All problems have four constraints: individual, economic, environmental, and social. To solve the problem, the player must first discover these constraints by exploring the game environment, and then the player must make a decision that satisfies all four constraints simultaneously. A solution that satisfies all four constraints is defined as a sustainable decision. The highest score a player can attain is through making sustainable decisions (see Fig. 6), any other decision is not sustainable. If the player does not make a sustainable decision, the game provides feedback.

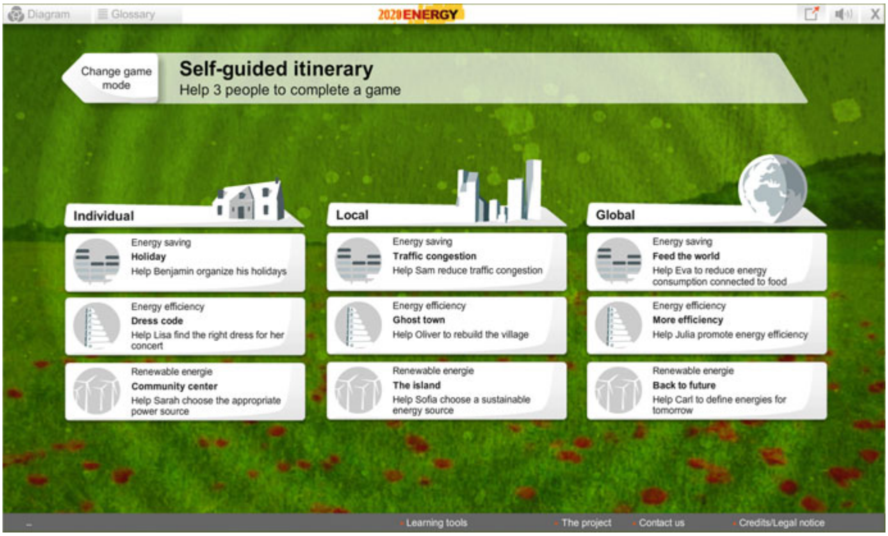


**Fig. 7** The nine-different energy mini-games in 2020 Energy

### 3.2.3 Replay and Promotion Mechanisms

There are no in-game mechanisms motivating replay, aside from improving a player's score. In terms of promotion, players can share a link to the game directly via Facebook, Twitter, and e-mail. The game also uses a web service that can send a link to the game via 300 different internet and social networking services.

### 3.2.4 Implementation

A typical mini-game proceeds as follows. A player is asked to help a game character solve a specific problem that involves energy and sustainability (refer to Fig. 8). The player explores the scene for clues that constrain the problem. For example, clicking on the map in the diagram pops up a bubble with the following information: "Since his friend Pierre came back from Amsterdam, he dreams about going himself." The player then can ask non-player character (NPC) experts for advice, further constraining the problem. These experts provide advice based on economic, environmental, and social consequences.

With the problem constraints discovered, the player proceeds to a decision screen (see Fig. 9) where he or she must choose one of several options, only one of which is sustainable.

After making a decision, the user can get feedback from the specific experts about its economic, environment, and social impacts by clicking on the icon representing the expert (see Fig. 10).


**Fig. 8** The problem screen. The problem has individual, economic, environmental, and social constraints, which can be discovered by clicking on the screen

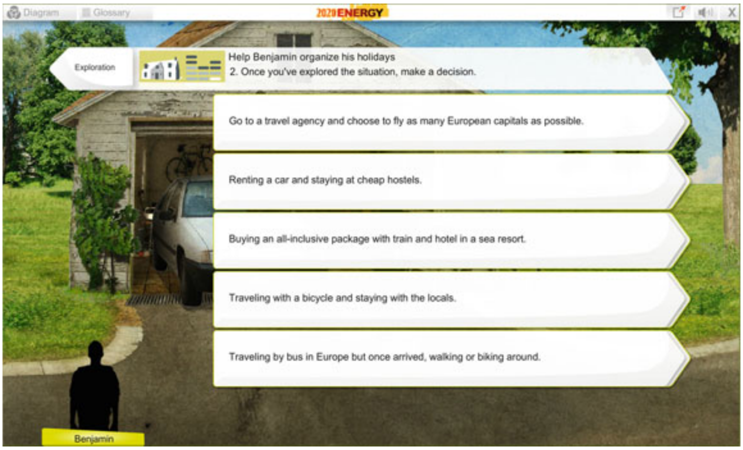


**Fig. 9** The decision making screen

Finally, the player receives a score, corresponding to a region in a Venn diagram for sustainability (see Fig. 11). As mentioned, the highest score corresponds to the Sustainable region of the Venn Diagram which is the intersection between the economy, the environment, and the social factors. The scoring screen also provides text that reinforces key points, and provides links to a video for further information.


**Fig. 10** Experts provide feedback on the player's decision in terms of its impact on the economy, the environment, and its social consequences

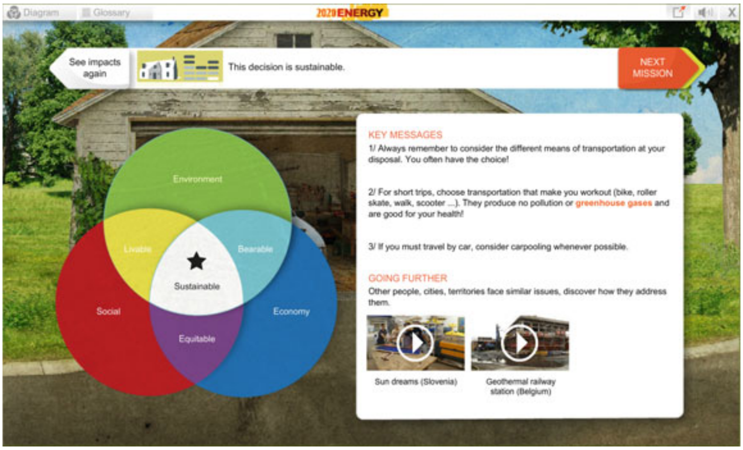


**Fig. 11** The scoring screen. The goal is to make a decision that lands in the sustainable region of the Venn Diagram

## *3.3 Power House*

Power House (powerhouse.stanford.edu) is an energy-themed serious game targeted at homeowners with smart meters. It was developed initially by Byron Reeves at Stanford University, with funding from the ARPAe Program in the Department of Energy. It was produced commercially in collaboration with Seriosity Inc., and Kuma Reality Games.

## 3.4 Goal

Power House is the most sophisticated energy-themed game to date, as it incorporates elements of creation, community, and commerce (Reeves, Cummings, Scarborough, Flora, & Anderson, 2012), and can be viewed as a kind of 2.5D3C game. The goal of Power House is to instruct the player on energy efficient behaviors.

### 3.4.1 Learning Mechanisms

Players learn these behaviors by playing mini-games such as turning off lights and appliances that are unnecessarily on. The energy consumed by these virtual appliances over time reflects actual appliance power levels. Thus, as players switch appliances off they acquire knowledge about power levels, which applies to appliances in their actual homes. Players can also swap out appliances for energy efficient versions and see the energy-saving consequences.

### 3.4.2 Replay and Promotion Mechanisms

Replay is incentivized in Power House through two general mechanisms: rewards and competitions. In terms of rewards, players earn virtual credits that they can redeem in the game for items like windmills and solar panels, which can increase their energy scores. They can also redeem virtual credits for actual rewards that are provided by partnering energy companies and foundations. In terms of competition, the game allows players to challenge other players.

But perhaps the most innovative feature of Power House is the importing of the user's actual home electricity use, via the home's smart meter data, into the game. This data then affects the actions the player is capable of performing within the world, the options and rewards received, and the reputation of the player. This is a dialectical process, where the player is motivated to apply the energy-efficient behaviors learned in the virtual world towards their actual world (home). In turn these behaviors affects in-game capabilities and social status, which motivates the player to continue playing the game.

For promotion, players can invite their Facebook friends to play.

### 3.4.3 Implementation

One of the mini-games is depicted in Fig. 12. In this game, a player must manage the energy needs of household members. Part of this management is the turning off of devices that are unnecessarily on. The power consumed by the various devices is depicted as a text overlay on an appliance. The game increases in complexity as


**Fig. 12** Power house mini-game screen

more household members join. Scoring is based on minimizing the overall energy consumed by the household.

A player's final score across the various mini-games is depicted in a dashboard (see Fig. 13), along with various incentive levels, achievements, and a graph of the energy use in the player's actual home.

## *3.5 Energyville*

Energyville (http://www.energyville.com/) is a web-only energy-themed serious game that targets a broad demographic consisting of individuals interested in the issue of managing energy at a city level, and the impacts of energy management decisions on the economy, the environment, and security. The game was funded by Chevron corporation, and was produced by the Economist Group.

### 3.5.1 Goal

The instructional goal of the game is to instruct players in the different kinds of energy sources, the structures and transportations at the city-level that consume these resources, and the impacts of different mixes of energy sources over time, on the economy, on the environment, and on security. The game goal is for the player

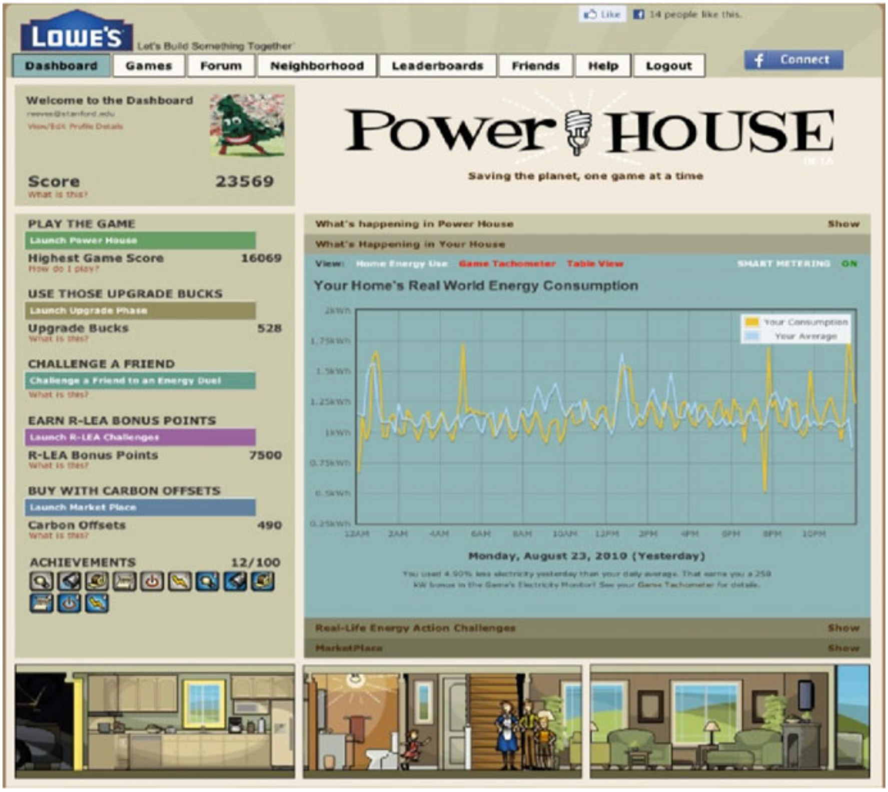


**Fig. 13** Power house scoring screen

to minimize, negative economic, environmental, and security impacts that result from the player's energy mix decisions.

### 3.5.2 Learning Mechanisms

The game has two rounds. In the first round the player adds a variety of different energy sources to the city, which power buildings and transportation vehicles. The energy sources are: biomass, coal, geothermal, hydro, hydrogen, natural gas, nuclear, petroleum, shale oil, solar, wind, and conservation efficiency. The buildings and transportation vehicles are: apartments, commercial buildings, factories, mass transit, office buildings, residential homes, airplanes, mass transit, trucking, and vehicles.

Prior to adding an energy resource, a player can learn about the energy needs of buildings and transportation vehicles; these needs are based on real-world values. The player can also learn about the benefits and costs of various energy sources and their positive or negative effects on the city's economy, environment, and security.

### 3.5.3 Replay and Promotion Mechanisms

The game motivate replay through competition. There are three kinds of competition. The first is a competition with other players across the globe. This is possible through a sophisticated comparison tool that allows players to compare their final scores with other players along the dimensions of gender, country, organization, and occupation. The second is competition between individual friends—a player can challenge a friend to try to beat his or her score. Lastly, a player can create a group game where invited friends can play, and only invitees can see the final scores.

For promotion, players can share a link to the game with friends via e-mail, twitter, and Facebook.

### 3.5.4 Implementation

The player starts off with a 3D representation of a city with structures and transportations that need to be powered by energy sources (see Fig. 14). The structures that do not have sufficient power are denoted by exclamation marks. The possible energy sources are depicted as a row of icons at the bottom of the screen. An Energy Advisor panel provides detailed information about the energy sources.

The player must solve the problem of powering the city using a mixture of the energy sources. A player's move consists of dragging the icons representing the energy sources onto empty spaces around the city, until the city is fully powered. Before dragging an icon, the player can click on an exclamation mark near a building or transportation vehicle in order to discover its energy needs (see Fig. 15). The data on energy needs is based on real-world values.

In addition to discovering information about energy needs, the player can get more information about the energy sources by hovering the mouse over its icon. This action updates the Energy Advisor panel with information about the costs and benefits of the energy source, as well as its economic, environment, and security impacts (see Fig. 16).

With an understanding of the city's power needs and the various energy sources, the player can drag icons representing the energy sources into empty spaces around the city until the city is fully powered up, which is denoted by the absence of all exclamation marks (see Fig. 17). The Energy Advisor has gauges that depict the impact of the mix of energy sources, and an energy management score.

The player continues the game play described above, for a second and final round. Before the final round, the game provides random information about events that have occurred such as global resource shortages or technological breakthroughs. The player must take into account these events when distributing energy sources in the next round, however the gameplay and learning activities are the same. After this final round the user is given an overall score (see Fig. 18).


**Fig. 14** Energyville's in its initial, unpowered state. See text for explanation


**Fig. 15** By clicking on the exclamation mark near a structure or transportation vehicle, the user can get information about its energy needs. This information is based on real-world data


**Fig. 16** By hovering the mouse over an energy source a user can get information about its benefits and costs, as well as its economic, environment, and security impacts


**Fig. 17** A fully-powered city

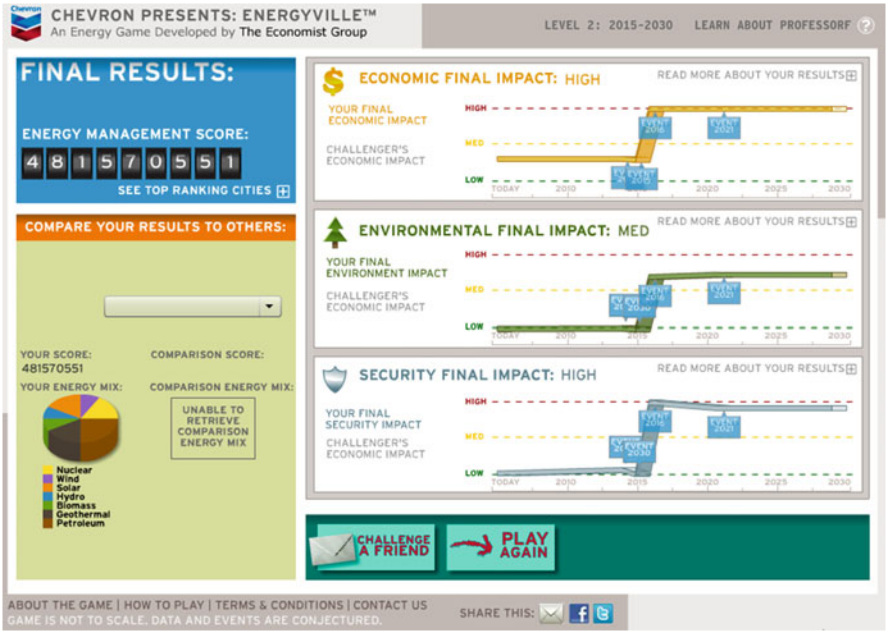


**Fig. 18** The overall score across the two rounds

## *3.6 Power Matrix (Siemens)*

Power Matrix (www.powermatrixgame.com) is a web-based energy-themed serious game developed by the Siemens Corporation, which targets users interested in energy management.

### 3.6.1 Goals

The gaming goal of Power Matrix is to achieve a high score. The details of the scoring algorithm are not known to the player, but it can be inferred from the game's instructions that it is a function of managing a mix of energy plants, generating revenue, keeping citizens satisfied, and trading energy with other players. The learning goals include knowledge about: different kinds of power generation plants; the effects of weather on renewables; energy storage; smart grids; and energy trading.

### 3.6.2 Learning Mechanism

Power Matrix is a complex energy simulation, with many mechanisms that instruct players in concepts unrelated to energy, e.g., trading. We will focus on just the mechanisms pertaining to energy learning. Players place power generation plants across the landscape of a city. If a power plant requires a particular kind of fuel, such as a combined cycle power plant requiring natural gas, the game informs the player about this dependency. In this way, a player learns functional relationships between power generation plants and their fuel sources.

For each plant, the user can discover information about energy production rates, fuel consumption rates, the operating costs, and citizen satisfaction. However, the values reported are unitless and are not tied to real-world levels, c.f., Chevron's EnergyVille. If players want information about actual values or more in-depth information about the plants, they are given the option of going to the Siemen's website. The game also implements a random weather system, which reports wind and sunlight levels, and allows players to see the effects of these levels on the energy produced by the solar and wind plants.

### 3.6.3 Replay and Promotion Mechanisms

The game runs continuously, even if the player is not logged on. If a player does not log in and play periodically, the city may grow to a level that requires more energy plants and the player's overall score will decrease. Thus, the main motivation for replaying the game comes from its continuous, real-time updates. Other sources of motivation to play are: (a) quests that provide virtual money that can be used to purchase in-game items; (b) daily login bonuses; (c) achievements that yield in-game rewards such as prestige buildings; and (d) competition with the scores of other players. Figure 19 is an example of a player receiving virtual money for playing on consecutive days.

For promotion, players can share a link to the game with their friends on Facebook or Twitter.


**Fig. 19** An example of daily rewards as a motivation for replaying the game. Players are motivated to play every day because doing so rewards them with virtual money that they can spend on in-game items

**Fig. 20** Power matrix starting landscape


**Fig. 21** Power plant options

### 3.6.4 Implementation Details

Players start off with a 2.5D representation of an empty landscape, except for an offshore subsea gas production facility, and a coal-mining facility (see Fig. 20). They must place power generation plants on this landscape. The player selects the different power plants via a build icon (hammer) at the bottom of the screen.

Clicking on the build icon pops up a window depicting the various power plant options (see Fig. 21).

Clicking on a power plant brings up a window with information about the energy production rates, fuel consumption rates, operating costs, population satisfaction,

**Fig. 22** Functional, cost, and real-world information about a power plant

**Fig. 23** A self-sustaining virtual city. *Top* and *side panels* provide real-time updates of the player's score and global rank (*top-left panel*), energy production and revenue (*top-right panel*) and weather conditions (*right panel*)

and the costs to build this plant (see Fig. 22). The player is also given information about real-world plants and is invited to find more information by clicking on a link to the Siemen's website. As mentioned, the learning is primarily functional as the values portrayed are unitless and do not correspond to real-world plant values.

The player continually places power plants on the landscape. This results in a self-sustaining city that provides real-time updates of energy production, revenue, and population, as well as where the player's score ranks globally, and the current weather conditions (see Fig. 23).

# 4 Summary: Goals and Mechanisms Applicable to a 3D3C Virtual Energy World

The review of existing energy-themed serious games suggest the following goals and mechanisms (learning, replay, promotional). Although these goals and mechanisms were based on 2.5D serious games, they are flexible enough to be implemented in 3D. Appendix also contains a summary of these goals and mechanisms.

## *4.1 Learning Goals*

Learning goals can include knowledge of: energy savings, efficient household behaviors; different kinds of energy sources; the costs, benefits, and impacts of energy sources on the economy, environment, security, and social groups; how to combine different energy sources effectively; the limitations of renewable energy sources; power requirements of appliances, building structures, and transportation vehicles; and how to make sustainable energy decisions at individual, local, and global levels.

## *4.2 Learning Mechanisms*

All the energy-themed experiences achieve their learning goals through repeated interaction of mini-games, rounds, or quests. We will refer to these collectively as energy problems. Games can pose energy problems to players at different levels, including personal, household, city, and global. Solving an energy problem requires first making one or more decisions that have impacts in terms of energy produced and consumed, the environment, the economy, society, and security. At the personal level, the decisions focused on everyday problems that a player would likely encounter, which would not seem to have energy implications, e.g., planning a vacation or deciding what dress to wear (see 2020 Energy). At the household level, these decisions focused on operating appliances and replacing energy inefficient appliances with energy efficient ones. At the city level, the decisions focused on the placement of different energy sources, which included biomass, coal, geothermal, hydro, hydrogen, natural gas, nuclear, petroleum, shale oil, solar, wind, and conservation efficiency: Prior to making a decision players needed to collect energy information on appliances, building structures, transportation vehicles, and energy sources, and impact information. The games provide this information to players, but they need to actively search for it.

### *4.3 Replay and Promotional Mechanisms*

All the games reviewed used replay mechanisms common to most video games and virtual worlds. In particular the games used scores as a motivation for improvement through replay. The score was a single number, except for 2020 Energy, which used the different areas of a Venn diagram as a visual indication of performance. Some games offered rewards and achievements badges for continuous play. Rewards were in the form of virtual credits that could be redeemed to purchase in-game items, or in some cases, real-world items from partnering organizations. Some games used competition to encourage replay. A basic competition mechanism was to make a global high score table available to players. More sophisticated competition mechanisms allowed players to challenge friends, or form group competitions. The need to replay was a natural consequence of real-time, continuously updated games like Power Matrix, which require continuous player maintenance. One replay mechanism specific to energy games was Power House's tying of actual home energy levels to abilities and rewards in the game. This results in a dialectical process where players apply the behaviors learned inside of the game, to their actual household, and then check the energy levels in the game. This leads to continued play using any new abilities or rewards earned.

Finally in terms of promotion mechanisms, all games gave players the ability to send a game link to a friend via Facebook. Twitter and e-mail were also platforms for sharing game links. Finally some games used a web service that could promote the game link across 300 internet and social media services.

The described goals and mechanisms can all be implemented in a 3D Virtual Energy World. The challenge is creating an environment that users will continuously play—as users need to spend significant time within virtual worlds for significant learning to occur. Yee (2006) argued that players in multi-user games were motivated by three main factors: achievement, social, immersion. Achievement was defined as the desire to *advance* power in the game, to understand game *mechanics*, and to *compete* with others. Social was defined as the desire to *socialize* with other players, build long-term *relationships* with other players, and deriving satisfaction through *teamwork*. Immersion was defined as the desire to *discover* things in the game that other players did not know, to *roleplay* different personas, to *customize* the appearance of avatars, or to *escape* from problems in the real world. Future research is needed to discover how to implement these factors as replay mechanisms within virtual worlds.

## 5 Conclusion and Future Research Challenges

Human-computer interaction expert Don Norman (1993) notes that, "In the real world, it is not possible to do actions that are impossible," and that designers of software simulations spend a significant amount of time testing and fixing their software so that users are prevented from doing anything that is impossible in the real world.

However, for virtual world designers, giving users the ability to do the impossible or the impractical can be a desirable feature, especially for topics like energy where renewable energy sources are currently too expensive for the average consumer, or where technologies are in the development stages, e.g., solar panels and energy harvesters, respectively.

Once users acquire a technology in a virtual world, they can safely experiment with it under suboptimal condition such as cloudy or windless days. They can also compress time in order to see the costs and benefits of these technologies across years or even decades. Thus, virtual worlds can help reduce much of the uncertainty associated with adopting these technologies in the future.

The main challenge for researchers designing energy-themed virtual worlds is to ensure that the costs, unintended consequences, and negative externalities associated with adopting and operating renewable energy technologies are represented accurately in the virtual world.

Virtual worlds represent normative statements about how the real world ought to be, which may embody a designer's biases and value judgments. For example, in the case of a solar-energy themed virtual world, the normative statement is that users should adopt photovoltaic technology as an alternative energy source. This is not an issue if the benefits, costs, and other systemic consequences of a user's actions in the virtual world reflect those in the actual world. However, designers may choose to only depict the beneficial features of a technology, and users may learn actions which are ultimately costly to individuals or the environment. Virtual world designers must include enough positive statements for users to make informed actions.

> The notion of positive and normative statements comes from economics. Positive statements contain factual and testable information about the real world, e.g., 48.61 million people do not have health insurance in the United States. Normative statements contain prescriptive actions, e.g., the government should provide healthcare to all uninsured citizens, which often include implicit value judgments.

Another important research topic is discovering effective ways of representing and visualizing energy-related information for learning purposes. Even basic concepts like wattage or kilowatt-hours are difficult for most people to understand. Fields like distributed cognition (Hollan, Hutchins, & Kirsh, 2000; Hutchins, 1995), that emphasize the analysis and design of effective representational systems, can help virtual world designers create better visualizations of energy concepts.

In closing, while impossible actions may be undesirable in high-fidelity simulations of the real world, as virtual world architects our designs are motivated by the belief that *in a virtual world it is possible to do actions that are impossible*. The key is to ensure that the consequences of actions in the virtual world reflect those in the real world, so that users acquire skills that are transferrable.

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## Appendix: Summary of Virtual Worlds Reviewed

| Name<br>*URL* | Goals | Learning mechanisms | Replay incentives and promotion mechanisms |
|---|---|---|---|
| Virtual energy world<br>*VirtualEnergyWorld.com* | Instruct players on the power requirements of common household appliances | Free-form exploration and energy quests | • Score improvement<br>• None |
| 2020 Energy<br>*2020energy.eu/game* | Provide players knowledge about reducing energy consumption, increase energy efficiency, and choosing the best renewable energy sources | Energy mini-games | • Score improvement<br>• Sharing link to game via social media |
| Power house<br>*powerhouse.stanford.edu* | Instruct the player on energy efficient behaviors | Energy mini-games | • Virtual credits redeemable for in-game items and for actual items<br>• Sharing link to game via social media |
| EnergyVille<br>www.energyville.com | Instruct players in the different kinds of energy sources, the structures & transportations at the city-level that consume these resources, and the impacts of different mixes of energy sources over time, on the economy, on the environment, and on security | Two-turn simulation | • Competition with players across the globe, with friends, and with groups<br>• Sharing link to game via social media |
| Power Matrix<br>*powermatrixgame.com* | Provide players knowledge about: different kinds of power generation plants; the effects of weather on renewables; energy storage; smart grids; and energy trading. | City-building simulation | • Continuously updating world, virtual money redeemable for in-game items, daily login bonuses, score competition<br>• Sharing link to game via social media |

## References

2020 Energy Teaching Sheet (n.d.). Retrieved July 30, 2014 from http://www.2020energy.eu/en/concepts-and-issues-addressed

Energy Information Administration. (2013, May 28). *Total energy>Monthly>Energy overview>Primary energy overview*. Retrieved June 7, 2013, from EIA-US Energy Information Administration: http://www.eia.gov/totalenergy/data/monthly/index.cfm

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI), 7*(2), 174–196.

Hutchins, E. (1995). *Cognition in the wild* (Vol. 262082314). Cambridge, MA: MIT Press.

March, S., & Smith, G. (1995). Design and natural science research on information technology. *Decision Support Systems, 15*, 251–266.

Marr, D. (1982). *Vision* (pp. 24–27). New York, NY: Henry Holt and Co.

Norman, D. A. (1993). *Things that make us smart: Defending human attributes in the age of the machine* (pp. 148–149). New York, NY: Basic Books.

Reeves, B., Cummings, J. J., Scarborough, J. K., Flora, J., & Anderson, D. (2012, May). Leveraging the engagement of games to change energy behavior. In *2012 International conference on collaboration technologies and systems* (pp. 354–358). IEEE.

Simon, H. A. (1969). *The sciences of the artificial* (136). Cambridge, MA: MIT Press.

Sivan, Y. (2008). 3D3C real virtual worlds defined: The immense potential of merging 3D, community, creation, and commerce. *Journal for Virtual Worlds Research, 1*, 1–32.

Whitney, G., Behrens, C. E., & Glover, C. (2010, November 30). *U.S. Fossil fuel resources: Terminology, reporting, and summary*. Congressional Research Service. Retrieved June 7, 2013, from http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.view&FileStore_id=04212e22-c1b3-41f2-b0ba-0da5eaead952

Yee, N. (2006). Motivations for play in online games. *CyberPsychology & behavior, 9*, 772–775.

# Simulating History in Virtual Worlds

**Nicola Lercari**

## 1 Virtual Worlds for History

Historical virtual worlds (HVWs) are 3D3C worlds (Sivan, 2008) that visualize the past and its relics or simulate specific socio-cultural dynamics and historical events. Virtual space, immediacy, and real-time simulation are characteristics that make 3D3C worlds unusual tools for historiography. One may wonder whether virtual worlds can be used in historical research, in the first place.

To address this problem, let's consider the general meaning of history through a quote by Edward H. Carr. This author defines History as "an unending dialogue between the present and the past" (Carr, 1961). Pondering this statement, it seems to me that the gap between history and virtual worlds diminishes, instead of growing. In fact, is there anything more relevant to the study of history than a HVW, meaning a potentially unlimited place of discussion where the relation between past and present can be represented in its own context and negotiated endlessly?

Indeed, historians, archivists, experts of material culture and heritage can use virtual worlds to negotiate information on the past and its memory with the protagonists of specific historical dynamics, along with their descendants and local communities. The value of historical 3D3C worlds is not limited to the public usage of history and the involvement of the masses in the interpretation of the past. Historical practitioners can use HVWs to re-enact the past and further advance their historiographical research on specific events and eras.

The notion that actions and conscious choices of the protagonists of history can be re-enacted is first introduced by Robin G. Collingwood in 1946. This author examines the process of historical explanation and describes the historian's necessity to mentally re-enact past experiences and actions (Collingwood, 1946). Hence,

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Collingwood pinpoints that re-enactment allows historians to criticize different interpretations of history and produce new knowledge on the past.

This chapter aims to reframe historical re-enactment in the digital era. HVWs can thus be used by historians to analyze the motivations and causes that led individuals to perform specific actions in the past. This is possible because the most important consequence of Collingwood's perspective is to have demonstrated that thoughts stand outside time and therefore past behaviors and choices can be understood by re-enacting the events the protagonists of history took part in (D'Oro, 2000).

## 2 Simulating History in Virtual Worlds

A 30-year long tradition of virtual reconstruction of built heritage can help us understand the conventions and consequences of historical simulation in 3D3C worlds. Since the first attempt to graphically reconstruct historical buildings in a computer—more precisely the virtual reconstruction of a Roman bath complex in England developed in 1983 (Woodward, 1991)—the simulation of the past and its relics has come a long way.

In the early 1990s museums around the world started employing computer-based simulations—defined "virtual rooms"—intending to engage their visitors with realistic representation of the past (Frisher, Niccolucci, Ryan, & Barceló, 2002). These digital visualizations did not possess strong scientific value since historians and archaeologists were not involved in the design and validation of the simulation.

The early virtual environments for archaeological investigation described by Maurizio Forte and Alberto Siliotti pledged to be scientifically accurate (Forte & Siliotti, 1997), but missed the opportunity to actively involve their users in the process of interpretation of the past and definition of social memory.

The practice of simulating the past went through a major shift in the early 2000s. Coleen Morgan argues that this change has been determined by the abandonment of immersive representations of the past based on expensive and unwieldy virtual reality devices. The early virtual environments for history were successfully replaced by more conceptual reconstructions "where users can directly interact with the environment and with others to build online social systems" (Morgan, 2009, p. 473). It is exactly in this context that the practice of using 3D3C worlds to simulate history first commenced.

Sequeira and Morgado pinpoint that the new modalities of virtual reconstruction in HVWs allow historical and archaeological practitioners to take the lead in the simulation process becoming the creators of the simulated scenarios (Sequiera & Morgado, 2013, p. 2).

The user-generated approach of 3D3C worlds enables the general public of the internet to participate in the co-creation of cultural meanings and share social memories. Critics to this approach may come from those opposed to a collaborative interpretation of the past and from those who fear that the open dimension of HWVs could undermine the validation of the historical content and, therefore, compromise the accuracy of the simulation.

Conversely, I argue that involving a higher number of individuals—defined by different classes, races, ethnicities, and gender—in the simulation and interpretation of the past allows scholars to expand their viewpoint on history and thus enhance their analytical capability. My point is that if a multitude of HVWs users participate in the negotiation of historical meaning, a larger critical mass provides beneficial comments and critiques to the hypothesis proposed in the virtual environment by historians. This condition helps the designers to enhance the hermeneutical value of the historical simulation in virtual worlds.

One may find similarities between the multi-perspective historical simulation of HVWs and the multi-vocal approach for the interpretation of the past proposed by I. Hodder (1997, 2000) and recently revised by Berggren et al. (2015). The analogy between these two approaches derives from a common interest to multiply the ways our past can be collectively interpreted through the negotiation of knowledge and historical meaning among a plurality of stakeholders.

## 3 The Principles of Historical Virtual Worlds

The problematic of historical re-enactment and simulation in HVWs needs to be addressed through the discussion of the fundamentals of these new platforms for historical research. A HVW based on the principles exposed in this section of the chapter conveys scientific representations of the past while refuting potential critics of lack of accuracy and scarce validation.

**Recognized Standards:** historical simulation in 3D3C worlds must comply with internationally recognized standards for the digital representation of the past—such as the *London Charter* (Beacham, Denard, & Niccolucci, 2006) or the *Seville Charter* (Denard, 2012).

**Validated Methodologies:** the recreation of built heritage in HVWs must employ previously validated methodologies for the reconstruction of buildings and landscapes, for instance a source-based virtual reconstruction relying on comparative analysis of historical sources (Lercari, 2010a).

**Replicable Practices of Data Gathering and Processing:** the information conveyed in HVWs needs to be gathered and processed using practices for data collection and dissemination specifically customized for a tridimensional representation of the past (Forte, Dell'Unto, Issavi, Onsurez, & Lercari, 2012). For the sake of accuracy, the employed practices need also to be easily replicable by others.

**Transparency of Data:** HVWs need to clarify the provenance of the displayed historical data as well as to provide statistics or visual clues on the level of uncertainty and ambiguity of the reconstructed scenario.

**Historical Circuit Reliability:** historians, archaeologists, or other experts of the past involved in the design of HVWs need to make sure that simulating history in 3D3C worlds depends on *historical circuit reliability*. This condition occurs when users of HVWs can visualize accurate and validated historical content while accessing metadata on its interpretation and reconstruction, directly within the virtual environment.

**Representation of Multiple Viewpoints:** in order to enhance the analytical capability of the simulation and its inclusiveness, HVWs need to convey different viewpoints on history—in terms of class, race, ethnicity, and gender.

**Embodiment in Historic Characters:** embodiment in avatars influence users' expectations and motivation in simulating history in HVWs (Bonini, 2008). Thus HVWs need to foster cognitive involvement and comprehension of historical information through avatars designed and costumed based on careful study.

**Place Making:** the design of HVWs poses the question of what defines a place and how to really achieve "placeness" in 3D3C worlds (Champion & Bharat, 2007). Virtual reconstruction of historical places thus requires an in-depth understanding of the ephemeral qualities of the simulated scenarios including the unique and dynamic nature of the environment. Hence, HVWs design needs to involve techniques of place making able to actively capture the culture and physiological experience of the simulated place and not only its tangible properties.

## 4 State of the Art in Historical Virtual Worlds

The value of historical 3D3C worlds derives from the capability of scientifically-accurate HVWs and historical re-enactment to help scholars understand how ancient civilizations developed their thoughts, actions, and cultures.

My analysis of the usage of 3D3C worlds for historical research relies on the assumption that the conscious choices of virtual worlds' users define a system of conceptual possibilities that informs us about the way people think and behave in real life. Thus, I argue that the data collected in historical virtual worlds can help historians and archaeologists develop new analysis and interpretations of the past and its relics. This condition only occurs when the virtual scenario is based on validated historical data and scientific virtual reconstruction.

This section strives to support my thesis through the discussion of seven case studies—selected among a vast number of projects and initiatives available online—that represent the state of the art of historical virtual worlds as of 2014.

The HVWs described in the following pages address historical simulation in a novel way. The goal is to define alternative methodologies of interpretation of the past based on new principles and techniques that rely on the new forms of perception and cognition available in the cyberspace.

**Fig. 1** Garisenda and Asinelli towers in thirteenth-century Bologna in Second Life

This analysis takes into consideration platforms developed from the second half of the 2000s through 2014 as academic initiatives or collaborations between museums and virtual worlds' specialists (Fig. 1).

The common denominators among the presented case studies is a strong emphasis on the simulation of scientifically accurate historical data along with the relevance of the social component in the interpretation of the past or the collaborative reception of cultural content by the general public as it is best exemplified by the public history research project Nu.M.E. 2010 (Lercari, 2010b).

### *4.1 Remixing Çatalhöyük*

| |
|---|
| PRODUCER: Open Knowledge and the Public Interest research group (OKAPI)—University of California, Berkeley |
| AUTHORS: Ruth Tringham, Michael Ashley, Coleen Morgan |
| ORIGINAL RELEASE: 2007 |
| DESCRIPTION: Archaeological virtual world that engages users in interactive experiences of a Neolithic town and promotes participatory pedagogy |
| HISTORICAL CONTEXT: Neolithic town of Çatalhöyük, Central Anatolia, current Turkey |
| TECHNOLOGY: Second Life, 3D Modeling, avatars, LSL scripting, multimedia |
| DATA ACQUISITION/POST PROCESSING: archaeological excavation |
| WEB: http://okapi.wordpress.com/projects/okapi-island-in-second-life/ |

*Remixing Çatalhöyük* is a cyber-archaeology initiative developed by the Open Knowledge and the Public Interest research group at the University of California, Berkeley in Second Life. The primary aim is to digitally recreate in a HVW the Neolithic site of Çatalhöyük—located in Central Anatolia, Turkey—where a group of archaeologists from UC Berkeley were invited by director Ian Hodder to experiment with new multivocal ways to investigate and represent the past. Çatalhöyük, is one of the first urban centers in the world (7100 BC–5600 BC) to present evidence of spectacular mural art works, artifacts, and mud-brick architecture. These features provide us with precious information on how life was 9000 years ago and make this proto-city a UNESCO World Heritage site as well as a fundamental milestone in the comprehension of the origins of agriculture and the first human settlements. The project visualized in Second Life a large amount of information collected onsite creating a *virtual settlement* open to alternative interpretations of Çatalhöyük history and architecture (Fig. 2). At the same time this virtual world was used as a platform for training undergraduate students and as a virtual gathering venue for discussing new digital ways to communicate the past. With this in mind, *Remixing Çatalhöyük* aimed to become a digital platform of discussion, collaboration and sharing of cultural information able to involve archaeological practitioners, students, and the general public in an open discussion on the origin of our civilization. Like many other historical virtual worlds in Second Life, *Remixing Çatalhöyük* faced overwhelming maintenance costs and was discontinued in 2012.

## *4.2 The Forbidden City: Beyond Space and Time*

| |
|---|
| PRODUCER: IBM and the Palace Museum of Beijing |
| AUTHORS: Wu Zhen, Michael Bacon |
| ORIGINAL RELEASE: 2008 |
| DESCRIPTION: Historical virtual world validated by historians whose simulation was enhanced by pedagogical videos, synchronous communication, and high interactivity between users and with autonomous non-player characters |
| HISTORICAL CONTEXT: The Forbidden City during Ming and Qing dynasty, Beijing, China |

(continued)

**Fig. 2** Neolithic buildings in Remixing Çatalhöyük

| |
|---|
| TECHNOLOGY: Custom avatar-based game engine developed by IBM, 3D modeling, render to texture, artificial intelligence to manage NPCs |
| DATA ACQUISITION/POST PROCESSING: historical sources, site survey, photographs |
| WEB: No longer available |

*The Forbidden City—Beyond Space and Time* is a virtual reconstruction initiative developed by IBM with the support of the Chinese government and the Palace Museum in Beijing. The main goal of this project is to create awareness of Chinese culture and history through a very realistic simulation of the Forbidden City in a HVW. The art and architecture of this stunning monumental complex have been symbols of the power and majesty of the Chinese emperors and their courts for five centuries. This historic virtual world—freely accessible online between 2008 and 2012—spanned an area of about a square kilometer including splendid monuments and buildings constructed by the Qing and Ming dynasties. Between 2006 and 2008 experts of Chinese heritage from the Palace Museum provided scientific guidance to a team of IBM 3D artists and programmers in the recreation of a very realistic environment able to portray the harmony and architectural balance of the Forbidden City. The game engine employed in *Beyond space and Time* has been developed by IBM with the goal to enhance online interaction between users and collective exploration of the historic scenario. Autonomous Non-player Characters (NPCs) provided information on the buildings and life of the Forbidden City while leading guided tours of the environment (Fig. 3). Users could collectively experience the ritual and daily life at the Qing court through interactive activities and game-like experiences enhanced by high quality 3D animation videos. This HVW was discontinued in 2013.

## *4.3 Theatron*[3]

| |
|---|
| PRODUCER: King's Visualization Lab—King's College London |
| AUTHORS: Mark Childs, Richard Beacham |
| ORIGINAL RELEASE: 2009 |
| DESCRIPTION: Historical virtual world that simulates a number of key historic theaters that belong to different cultures and eras |
| HISTORICAL CONTEXT: Multiple |
| TECHNOLOGY: Second Life, 3D modeling, avatars, render-to-texture, LSL scripting, motion tracking and gesture analysis |
| DATA ACQUISITION AND POST PROCESSING: comparative analysis of archaeological data and historical sources |
| WEB: http://cms.cch.kcl.ac.uk/theatron |

In 2002 the THEATRON project was started by King's Visualisation Lab at King's College London with the support of Eduserv. Initially THEATRON investigated and virtually reconstructed 19 theatre buildings belonging to different eras

**Fig. 3** Avatars interaction in beyond space and time

as milestones in the development of European theatre design (Fig. 4). At an early stage, THEATRON relied solely on a stand-alone interactive application able to render simplified versions of the virtual theaters and presented in-context pre-rendered images and animations of the related high quality models along with metadata and images about them. In 2009 *Theatron*[3] was launched to transform the initial virtual reconstructions of THEATRON into a vast historical virtual world within Second Life. The aim of *Theatron*[3] is to provide highly innovative, interactive teaching and learning resources that allow students from five higher education institutions to collaborate and learn within the HVW. This historical 3D3C world has the merit to have fostered the study of historical simulation as a tool for interpreting and visualizing the past. In addition, *Theatron*[3] verified that Second Life is not the most suitable platform to simulate theater performance that already exist in reality world, but that it has a lot of potential as a medium able to explore new forms of performative arts (Childs, 2009). Particularly relevant is the usage of advanced LSL scripts to make the scenarios interactive as well as to enable the creation of avatar-based theater performances in the HVW.

### 4.4 Nu.M.E. 2010

| |
|---|
| PRODUCER: University of Bologna |
| AUTHORS: Nicola Lercari, Francesca Bocchi, Antonella Guidazzoli |
| ORIGINAL RELEASE: 2010 |
| DESCRIPTION: Historical virtual world validated by historians that simulates urban space and daily life in the Late Middle Age |
| HISTORICAL CONTEXT: Thirteenth-century Bologna, current Italy |

(continued)

**Fig. 4** The Theater of Epidaurus in Second Life

| |
|---|
| TECHNOLOGY: Second Life, 3D Modeling, avatar design, LSL scripting, cloud computing and in-world web browsing |
| DATA ACQUISITION/POST PROCESSING: comparative analysis of historical sources |
| WEB: http://www.cineca.it/en/progetti/new-electronic-museum-city-four-dimensions-virtual-bologna |

*Nu.M.E.* (New Electronic Museum) is a multidisciplinary research initiative developed at the University of Bologna and Cineca Supercomputing Center in Italy. *Nu.M.E.* started in the late 1990s with the goal to experiment new methodologies in the field of urban history and cultural visualization. In 2010 a new version of *Nu.M.E.*—known as *Nu.M.E. 2010*—was developed in Second Life, more precisely in a SIM owned by the University of California Merced, called *Heritage Island*. The aim of *Nu.M.E. 2010* is to define new methods for the dissemination of historical information on the late Medieval Bologna and to reinterpret the urban space of this early city through storytelling, embodied interaction, and geographical cloud computing (Lercari, Toffalori, Spigarolo, & Onsurez,2011). Covering an area of about half a square kilometer, this virtual world simulates several buildings and monuments in downtown Bologna (Fig. 5). It also portrays the cloth market held in Porta Ravegnana square at the hearth of the city and allows users to re-enact a daily life scene in thirteenth century. Between 2010 and 2012 the users of *Nu.M.E. 2010* collaborated in the HVW to redefine and reinterpret the historical meanings embedded in the simulation using re-enactment, in-world internet browsing, and cloud computing platforms for mapping geographical and historical content. Like many other historical virtual worlds in Second Life, *Nu.M.E. 2010* faced overwhelming maintenance costs and was discontinued in 2012.

**Fig. 5** Cloth market in thirteenth-century Piazza di Porta Ravegnana, Bologna in Second Life

## *4.5 Teramo: A City Virtually Dressed*

| |
|---|
| PRODUCER: University of California, Merced—Teramo Archaeological Museum—Cineca |
| AUTHORS: Maurizio Forte, Nicola Lercari, Fabrizio Galeazzi, Davide Borra |
| ORIGINAL RELEASE: 2010 |
| DESCRIPTION: Archaeological virtual world that simulates monumental complexes and private houses of the Roman city of Interamnia |
| HISTORICAL CONTEXT: First century BC—second century AD Interamnia, current Teramo, Italy |
| TECHNOLOGY: 3D Modeling, OpenSimulator, multimedia |
| DATA ACQUISITION/POST PROCESSING: Comparative analysis of archaeological data and historical sources |
| WEB: http://www.3dmetaversity.org/site/default.asp?lingua=1 |

*Teramo—A city virtually dressed* (TaCVD) was created in 2009 as a joint research initiative involving the University of California Merced, the City of Teramo and the Institute of Technologies Applied to Cultural Heritage at CNR, Rome. The aim of this project is to virtually reconstruct in the open source platform OpenSimulator the archaeological context of the Roman city of Interamnia—the current Teramo, in central Italy—on the basis of the key archaeological areas of its urban network. Despite the importance of Interamnia from an archaeological point of view, the fragmentation of the sites—mostly hidden or decontextualized—and the difficulties to communicate them a in broader sense, made it difficult for archaeological and museum practitioners to conduct an adequate cultural communication of the city's heritage. TaCVD was created to find solution to this issue and to test new uses of public archaeology in the open virtual world *3DMetaversity* hosted at Cineca supercomputing center. Between 2010 and 2011 TaCVD became the first historical virtual worlds in OpenSimulator to promote an open approach to the simulation of the past (Forte, Lercari, Galeazzi, & Borra, 2010). TaCVD

**Fig. 6** The Roman Theater of Interamnia in OpenSimulator

featured key ancient Roman monuments of Interamnia, more precisely the Roman Theater and the Lions' Domus (Fig. 6). In addition, the creation of a virtual library, known as *Virtuoteca*, provided users with an in-world meta-space for gathering and exchanging archaeological information on the simulated sites.

## 4.6 *Virtual Middletown Living Museum*

| |
|---|
| PRODUCER: Ball State University—Institute for Digital Intermedia Arts (IDIA) |
| AUTHORS: John Fillwalk and IDIA staff |
| ORIGINAL RELEASE: Pilot available in 2011—currently under development |
| DESCRIPTION: Historical virtual world that simulates twentieth-century Ball Brothers Glass Manufacturing Co. fostering virtual re-enactment of contemporary history |
| HISTORICAL CONTEXT: 1920s–1930s Muncie, in the state of Indiana, United States |
| TECHNOLOGY: Blue Mars, 3D modeling, advanced lighting based on graphics shaders, NPCs animation, advanced scripting, spatialized sound |
| DATA ACQUISITION/POST PROCESSING: Comparative analysis of historical photographs and sources |
| WEB: http://cms.bsu.edu/about/administrativeoffices/hybriddesigntech/researchanddesign/contractedservices/virtualworlds |

The *Virtual Middletown Living Museum* is a pilot project currently developed by the Institute for Digital Intermedia Arts (IDIA) in collaboration with the Center for Middletown Studies and University Libraries at Ball State University. The project aims to simulate the socio-historical scenarios at the core of the 1929 and 1937 *Middletown Studies* authored by Robert S. Lynd and Helen M. Lynd as a series of sociological case studies that focus on cultural norms and social change in 1920s–1930s America. This historical virtual world simulates an archetypical industrial context from the town of Muncie in Indiana—the Ball Glass Factory as it was in 1920s—engaging users in a highly realistic immersive experience based on historical re-enactment and interactive activities (Fig. 7). *Virtual Middletown Living Museum* enhances the learning process typically available in open-air museums (e.g. Colonial Williamsburg) providing historical information, metadata, and

**Fig. 7** Virtual Middletown living Museum in Blue Mars

historical photographs directly within the HVW. The Ball Glass Factory setting serves as a prototype for a larger virtual world, currently under development, that will reconstruct the whole cultural landscape of Middletown as well as will simulate elements of private and religious daily life representing Muncie's dwellings and churches.

## *4.7 Venice Virtual World*

| |
|---|
| PRODUCER: Duke University—Wired! Lab |
| AUTHORS: Nicola Lercari, Kristin Lanzoni, Virtual Form and Space 2013–14 course students, Wired Lab fellows |
| ORIGINAL RELEASE: Pilot available in 2014—currently under development |
| DESCRIPTION: Historical virtual world that simulates the island of Santa Lucia in Venice before Napoleonic occupation and the advent of train completely transformed its urban landscape |
| HISTORICAL CONTEXT: 1740s Venice, current Italy |
| TECHNOLOGY: OpenSimulator, 3D modeling, advanced lighting based on graphics shaders, LSL scripting, ESRI ARC GIS, Bundysoft L3DT, Bayliwick, Omeka and Neatline for management and display of historical sources |
| DATA ACQUISITION/POST PROCESSING: Comparative analysis of historical sources |
| WEB: http://www.dukewired.org/projects/venice-virtual-world/ |

Venice Virtual World (VVW) is an educational project developed with the contributions of postdoctoral scholars, undergraduate, and graduate students at Duke University. The project aims to engage students by combining the study of art history with visual and new media studies. VVW recreates the life of Venice, its buildings, bridges, boats, gardens, and inhabitants in a 3D3C world that simulates the Island of Santa Lucia as it was in 1740s (Fig. 8). The focus of the historical

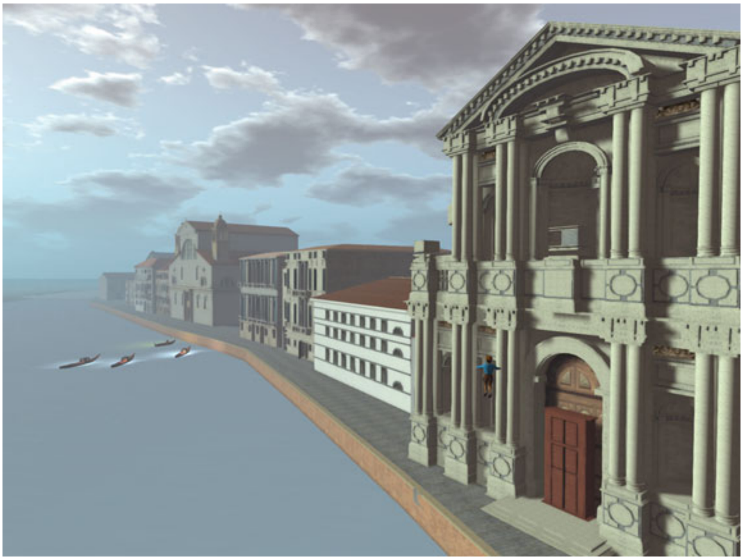

**Fig. 8** View of buildings and churches in Venice Virtual World

simulation is on the now completely transformed zone of the city around the train station. Using a geographic information system (ESRI ARC GIS) and digital terrain tools (Bundysoft L3DT and Bayliwick), historic maps of Santa Lucia were transformed in a scientific, 1:1 scale reconstruction of the island. Students reconstructed the urban landscape using drawings, building plans, views of monuments and interiors. Avatars—designed and costumed based on careful study—interact within this virtual world and guide users to explore the reconstructed urban space. VVW users can access primary and secondary historical sources through small interactive kiosks that connect to an online content management system (Omeka). The pedagogical approach of VVW results in immersive, active engagement with the experience of what it would have been like to inhabit a particular space at a key historical moment.

## 5 Conclusions

This chapter focused on the analysis of the cultural role of historical 3D3C worlds as well as on the discussion of the effects of historical simulation on the general public and local communities. Drawing upon the theories and facts discussed in the previous pages, one infers that the power of historical simulation and virtual reconstruction derives from the capability of HVWs to attract people inside the simulated historical context. HVWs involve users in a synesthetic process of creation of historical meaning in which both tangible and intangible elements of the past can be discussed, shared, and understood (Lercari, 2010a, p. 130).

This chapter strived to demonstrate that the power of HVWs is to expand the historians' capability to study the past by enabling new types of re-enactment and interpretation that involve minds and bodies. For instance, users of HWVs can re-enact past experiences embodying themselves in avatars that represent historical characters. Through their new electronic bodies users can retrace the conscious choices of individuals that made history or that simply lived in a specific era.

Maurice Merleau-Ponty assigns a fundamental role to our body arguing that the cognition and interpretation of the world where we live occur through our sensori-motor system (Merlot-Ponty, 1945). In addition, Francisco Varela, Evan Thompson, and Eleanor Rosh emphasize the importance of *embodied mind*, *situated cognition* and *enaction* in the interpretation of complex data (Varela, Thompson, & Rosh, 1993).

In my perspective, the comprehension of historical content in HVWs is thus deeper than in other types of historical simulations. This occurs because HWVs users—embodied in historical characters—experience the simulated scenario through the virtual bodies of their avatars while collectively re-enact the past and negotiate historical meaning between one another.

The power of simulating history in 3D3C worlds is expanded by new peculiar typologies of *causation*, *emotional involvement*, *spatiality*, and *temporality* that cannot be found in any other media. These unique features allow historical practitioners to represent continuities and discontinuities of history in a tridimensional virtual environment based on scientific data.

Drawing upon Michel Foucault theories on the production of knowledge in historical disciplines (Foucault, 1969), I argue that historical simulations strongly affect the ways our society understands its history or the modalities in which local communities develop their own social memory.

The approach to historical simulation discussed in this chapter refer to Ian Hodder's theory stating that our representations of the past derive from analytical models that are themselves interpretations of our reality. Thus, different people may have different interpretations of the same past phenomenon or event (Hodder, 1997, 2000).

The *multivocal approach to simulating history* proposed in this chapter stresses the significance of visualization and re-enactment of history in 3D3C worlds both as tools for the interpretation of the past and as resource that enable a collective negotiation of the meaning of cultural heritage. In the proposed perspective, the multiple points of view on history conveyed by HVWs add a multitude of critical voices and viewpoints to the interpretation of the past suggested by historians and archaeologists. As a consequence, the analytical capability of HVWs is enhanced.

In addition, this chapter strived to demonstrate that when HVWs follow validated standards and principles for the simulation of the past (for example the *London Charter in Second Life* or the *Seville Charter*) they acquire universal historical validity and become platforms capable of conveying valid knowledge about our past and heritage. The new forms of *spatiality*, *temporality*, and *causation systems* typical of HVWs assign a new role to the *emotional involvement* of users in their heritage. As noted by Gaynor Bagnall, emotions and memory thus play a fundamental role in the consumption process of cultural heritage (Bagnall, 2003). At the same time, such properties generate new embodied cognitive opportunities for HVWs users, allowing them to understand the complex meanings embedded in the simulated environment.

Thus, this chapter claims that HVWs users develop a deep comprehension of simulated historical contexts through their avatars. The embodied cognition processes available in HVWs allow users of 3D3C worlds to become protagonists of pervasive re-enactment of historical events.

To conclude this discussion on the usage of 3D3C worlds in history, one needs to specify that archaeologists, historical practitioners, and other scholars involved in the study of cultural heritage have the responsibility to identify new truthful ways to represent the past in HVWs, or better the many pasts of which our history is constructed.

Scholars in these fields can thus utilize the new types of space, time, causation systems, and cultural artefacts described in this chapter to re-enact and simulate history in virtual worlds, opening new horizons to the study of the past using 3D3C worlds.

## References


Bagnall, G. (2003). Performance and performativity at heritage sites. *Museum and Society, 1*(2), 87–103.

Beacham, R., Denard, H., & Niccolucci, F. (2006). An introduction to the London Charter. In M. Ioannides et al. (Eds.), *The e-volution of information communication technology in cultural heritage: Where hi-tech touches the past: risks and challenges for the 21st century* (pp. 263–289). Budapest: Archaeolingua.

Berggren, Å., Dell'Unto, N., Forte, M., Haddow, S., Hodder, I., & Issavi, J. (2015, Spring). Revisiting reflexive archaeology at Çatalhöyük: Integrating digital and 3D technologies at the trowel's edge. *Antiquity*, *89*(344), 433–448.

Bonini, E. (2008). Building virtual cultural heritage environments: The embodied mind at the core of the learning process. *International Journal of Digital Culture and Electronic Tourism, 1* (2-3), 113–125.

Carr, E. H. (1961). *What is history?* New York: Vintage Books.

Champion, E., & Bharat, D. (2007). Dialing up the past. In F. Cameron & S. Kenderdine (Eds.), *Theorizing digital cultural heritage* (pp. 333–348). Cambridge, MA: MIT Press.

Childs, M. (Ed.). (2009). *THEATRON Final report*. King's College London. http://cms.cch.kcl.ac.uk/theatron/fileadmin/templates/main/THEATRON_Final_Report.pdf.

Collingwood, R. G. (1946). *The idea of history*. Oxford: Oxford University Press.

D'Oro, G. (2000). Collingwood on re-enactment and the identity of thought. *Journal of the History of Philosophy, 38*(1), 87–101.

Denard, H. (2012). A new introduction to the London Charter. In A. Bentkowska-Kafel, D. Baker, & H. Denard (Eds.), *Paradata and transparency in virtual heritage digital research in the arts and humanities series* (pp. 57–71). Farnham: Ashgate.

Forte, M., Dell'Unto, N., Issavi, J., Onsurez, L., & Lercari, N. (2012). 3D archaeology at Çatalhöyük. *International Journal of Heritage in the Digital Era, 1*(3), 351–378.

Forte, M., Lercari, N., Galeazzi, F., & Borra, D. (2010). Metaverse communities and archaeology: The case of teramo. In *Proceedings of Third International Euro-Mediterranean Conference—EuroMed 2010* (pp. 79–84).

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.

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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

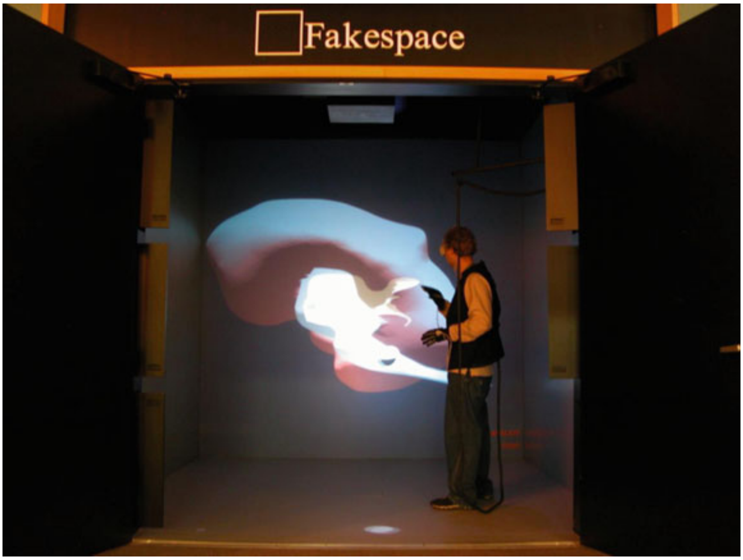


**Fig. 3** Virtual kidney

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).

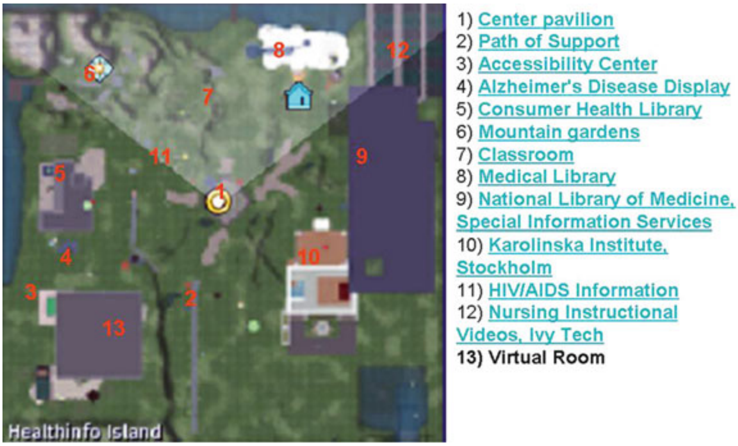


**Fig. 4** Healthinfo Island (Second Life)


**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

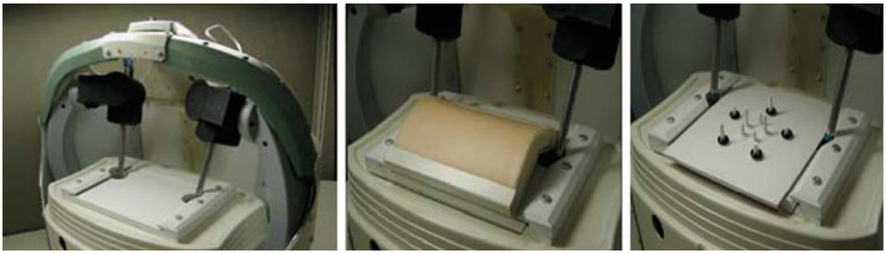

**Fig. 7** CELTS simulator

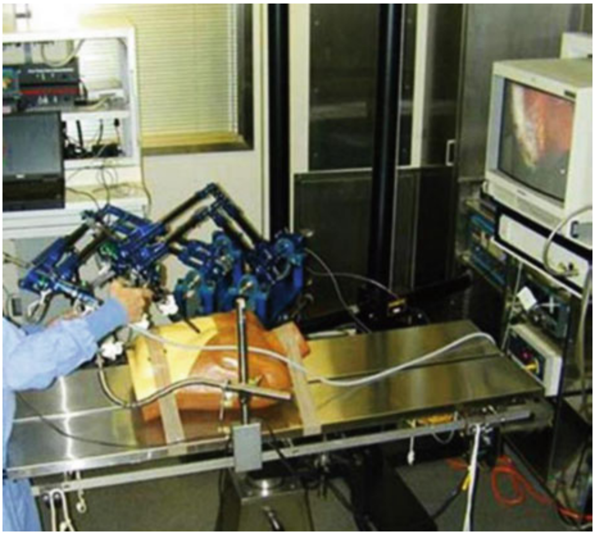

**Fig. 8** The Blue Dragon

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

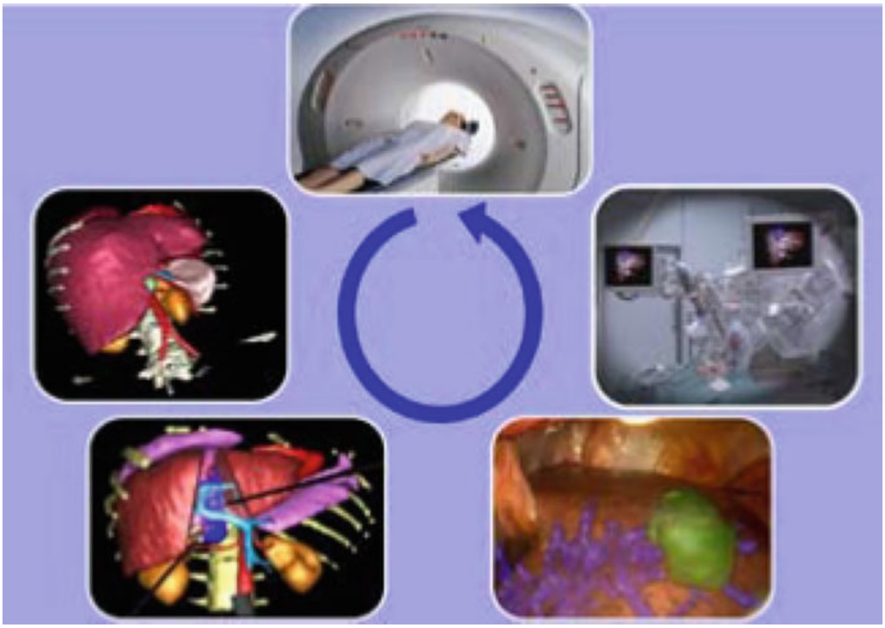

**Fig. 9** Augmented Reality

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

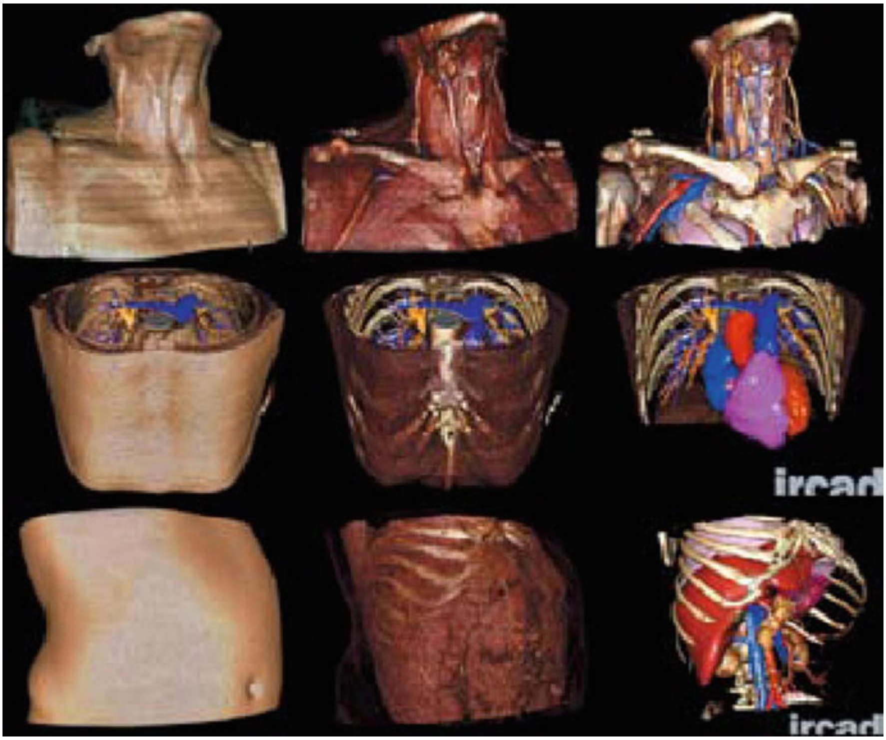


**Fig. 10** Direct Volume Rendering

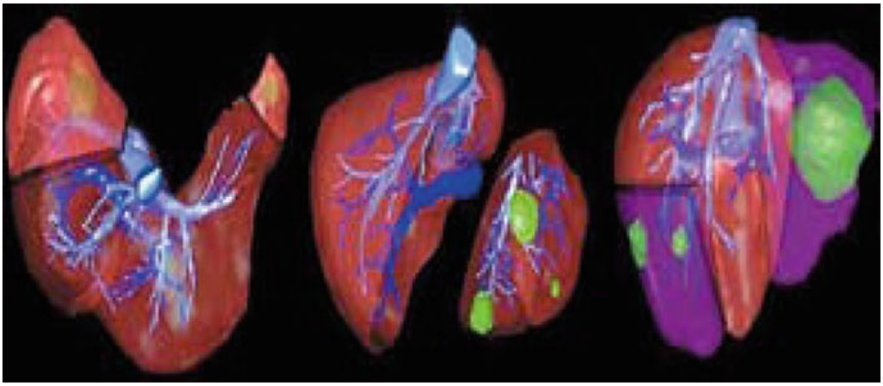

**Fig. 11** Rendering

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

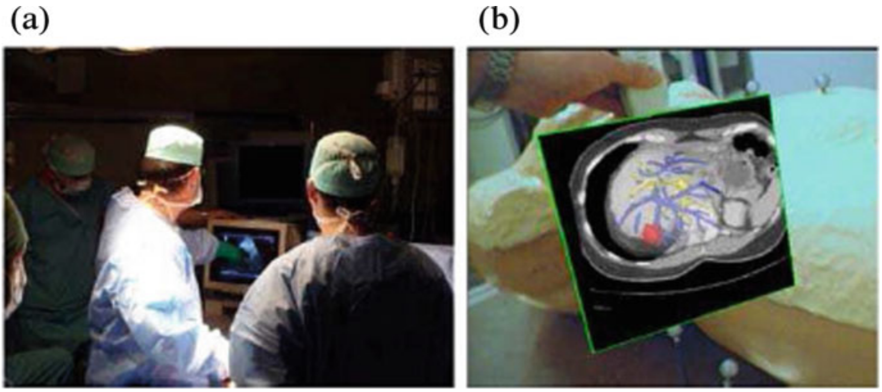


**Fig. 13** Overcoming the problem of hand-eye coordination using Augmented Reality. (**a**) Typical examination using sonography. (**b**) The AR display enables the user to see the data at the same location where his/her hands operate

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 |

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|---|---|---|---|
| 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 |

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**Table 4** (continued)

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|---|---|---|---|
| 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 |

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|---|---|---|---|
| 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

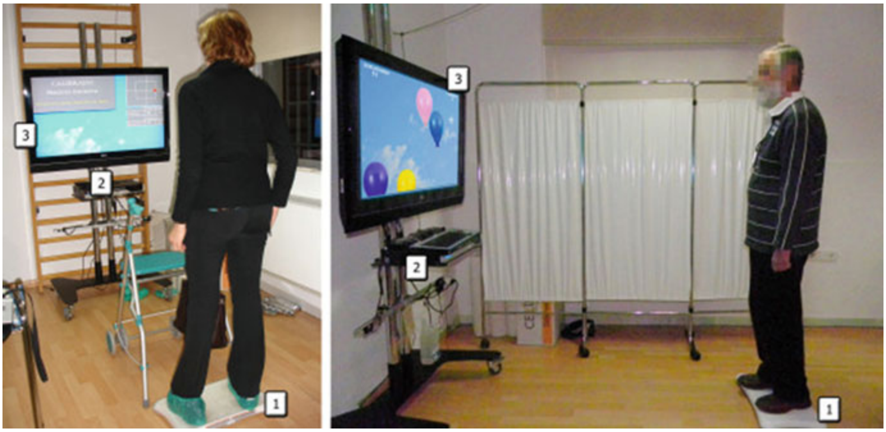


**Fig. 16** Ebavir


**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.

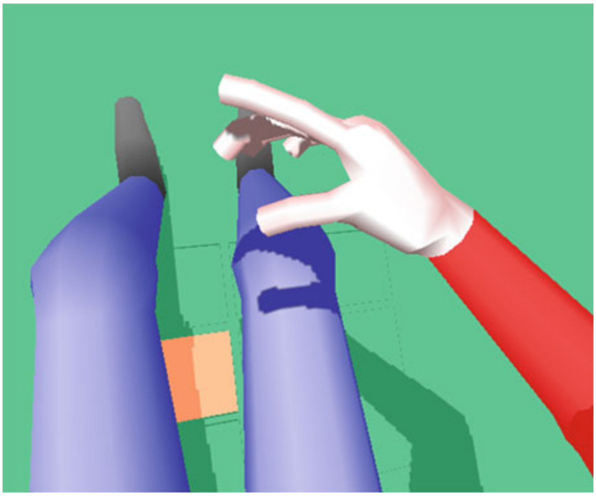

**Fig. 19** Reconstructed limb with Oculus Rift

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 ($<$19 years old) reporting significantly higher ratings for realness and presence than adult subjects ($\geq$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

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[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

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 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.

# Computer-Simulated 3D Virtual Environments in Collaborative Learning and Training: Meta-Review, Refinement, and Roadmap

**António Correia, Benjamim Fonseca, Hugo Paredes, Paulo Martins, and Leonel Morgado**

## 1 Introduction

In recent years, 3D3C worlds have been mentioned in literature as viable platforms for e-learning and distance education (Callaghan et al., 2009), with expectations of a large and increasing impact on teaching and learning in higher education for the near future (Hew & Cheung, 2010). This is particularly manifested by the institutional adoption of Second Life and OpenSimulator, as well as the more sporadic use of other platforms such as World of Warcraft for educational activities (e.g., language teaching). The perceived benefits of their visual immersive components in the context of students' learning range from an augmented sense of reality (Anstadt et al., 2013) to the enhanced spatial knowledge representation, increased intrinsic motivation and engagement, improved transfer of knowledge and skills to real situations through contextualization of learning, and richer collaborative learning than is possible with 2D alternatives (Dalgarno & Lee, 2010). Immersive multi-user virtual worlds have been recently adopted as cost-effective solutions for creating simulations in a vast set of application areas, including space exploration, virtual laboratories, healthcare and emergency response, cultural heritage and

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archaeology, military training, engineering, urban planning, and economics (Jarmon et al., 2009; Allison et al., 2012). These hybrid virtual ecosystems provide an experience which transcends cultural, social, language, distance, and temporal barriers through different modes of interaction (Anstadt et al., 2011), allowing a way to creatively explore critical thinking (Phillips & Berge, 2009) while supporting collaborative learning strategies and activities within which every learner agent plays an essential role. Although many studies have shown the interest of students in immersive multi-user virtual worlds, the full potential of the use of various kinds of 3D3C worlds for teaching and learning is still to be realized (Dalgarno & Lee, 2010; Allison et al., 2011; Duncan et al., 2012).

This chapter extends and allows the refinement of Correia et al.'s (2014) meta-analysis on the current challenges and opportunities of simulated environments for education and training. "Computer-based Simulated Environments: From Technology to Social Engineering" presents some background on virtual worlds with emphasis on its history and applicability. "The Unrealized Potential of Virtual Worlds for Teaching and Learning: Meta-Analysis" introduces the method and the sample dimensions concerning the metadata extracted, and "Discussion" discusses their implications in the form of theoretical framework. Finally, some concluding remarks are provided in "Final Thoughts."

## 2 Computer-Based Simulated Environments: From Technology to Social Engineering

Historically, visual multi-user virtual worlds have been around since the late 1980s, and some even before as "hardware-only systems" (Joslin et al., 2004), incorporating technical improvements such as simulators, stereoscope, 'cinerama', head-mounted displays, and trackers (Grady, 1998). Text-based and 2D perspective virtual environments date from even earlier in the form of systems such as text-based multi-user virtual worlds or Multi-User Dungeons (MUD) and similar MUD-inspired systems (Bartle, 2010). The first known studies reporting results of educational practices with virtual worlds in the form of MUD were presented in the 1990s. Such studies mentioned aspects related with changes in educational dynamics, students' and teachers' behavior, online identities, technological issues, and pragmatic concerns on the management of these platforms (Haynes & Holmevik, 1998). Other topics studied in the first decades included location and time dependencies, reality vs. virtuality, anonymity vs. true identity, human vs. technological factors, level and scale of immersion, play vs. work, and presence vs. telepresence. In this sense, Jäkälä and Pekkola (2007) argued that the research efforts on virtual worlds have transited "from considering them as tools to examining their use, from technology engineering to social engineering". While the focus relapsed on the technological aspects of 3D3C worlds, there has been a need for understanding social interaction, comparing the magnitude of co-presence (Bailenson & Yee, 2008). A key purpose of "social virtual worlds" relies on the co-construction of a shared meaning through object handling and communication between different people within a world (Damer, 2008). Stangl et al. (2012) summarizes success factors from scientific studies, pointing the support for a critical mass of residents as one of the several success factors attracting users.

Inter-user, avatar-mediated communication is essential for an understanding of the potential of virtual worlds for learning and training (Morgado et al., 2010). 3D3C worlds can be understood as immersive virtual worlds within which people can interact with software agents "using the metaphor of the real-world but without its physical limitations" (Davis et al., 2009). Furthermore, Ghanbarzadeh and colleagues (2014) define a three-dimensional virtual world as "a computer-simulated electronic 3D virtual environment that users can explore, inhabit, communicate, and interact with via avatars, which are graphical representations of the users". Such simulated environments can also be described as 3D spaces populated by avatars which support collaborative learning, work and social play (Benford et al., 2001; Duncan et al., 2012) or more generically as multi-user spatial environments within which the interaction paradigm is that of user-embodied avatars, regardless of the visual representation (e.g., the 3D space may be described via 2D perspectives or in textual form, as stressed by Morgado et al., 2010). Synoptically, 3D3C worlds can be seen as collaboration ecosystems that minimize the risk of complex tasks through simulation abilities. According to Bentley et al. (1992), such technology "may support some aspects of social interaction not readily accommodated by technologies such as audio-and video-conferencing and shared desktop applications", encouraging peripheral awareness in processes such as content sharing and artifact production.

The development of digital ecologies has been marked by media spaces, virtual worlds, mixed reality, and hybrid ecologies that merge the mixed reality with ubiquitous computing "to bridge the physical-digital divide" (Crabtree & Rodden, 2008). A computer-based simulated environment provides several features for creating an online presence that can replicate real-world scenarios in multi-user settings. Such environments enable social interaction through several communication channels (e.g., text, audio, graphical icons, visual gestures, and multisensory inputs). They also support coordination actions, and allow cooperation settings by using shared applications to track changes and manipulate (or interact with) digital artifacts for which team members can jointly look at (Schroeder et al., 2006; Jarmon et al., 2009). Immersive realism, interoperability, scalability, and ubiquity of access and identity are considered critical elements of a viable 3D3C world, and more research is needed "to provide context for considering the present state and potential future of 3D virtual spaces" (Dionisio & Gilbert, 2013). From text-based virtual worlds to the open development of metaverse platforms (e.g., Open Source Metaverse), collaborative learning has been a topic which requires a clear focus.

Earlier studies on collaboration dynamics using 3D3C worlds identified potential features for enhancing peripheral awareness (Bentley et al., 1992). Recently, research suggests that computer-based simulated environments can be well-suited for experiential learning activities (Jarmon et al., 2009), organizational learning

(Dodgson et al., 2013), business simulations (Mak & Palia, 2014), information systems auditing (Moscato & Boekman, 2014), and game-based learning (Sung & Hwang, 2013). Furthermore, healthcare approaches such as dentistry (Phillips & Berge, 2009), medical learning (Wiecha et al., 2010), cardiopulmonary resuscitation (Creutzfeldt et al., 2010), stress inoculation training (Serino et al., 2014), and healthy aging (Paredes et al., 2014; Siriaraya et al., 2014) have also been supported. Other application areas include virtual tourism (Warburton, 2009), archaeology (Sequeira et al., 2014), aerospace engineering design (Okutsu et al., 2013), training processes in the context of mechanical maintenance tasks (Fonseca et al., 2011), and military operations, tactics and strategies requiring sophisticated technologies for preparing troops to real combat scenarios (Pierzchała et al., 2011). Figure 1 presents a collaborative task performed in a computer-simulated 3D virtual environment. As argued by Fonseca et al. (2011), the adoption of a 3D virtual learning environment for training contributes to increase the efficiency of certain phases by enabling trainees to perform simulated activities without the involvement of physical resources.

Regarding the potential of such environments for higher education, researchers have been focused on the identification of requirements and potential benefits of project-based instruction and collaboration. In particular, researchers have found opportunities associated with increased sense of shared presence, social interaction and collaborative learning, partially liquefied social boundaries, and lowered social anxiety. In this context, the Collaborative Learning Environment with Virtual Reality (CLEV-R) was an example of a technical development for enhancing the afore-mentioned aspects (Jarmon et al., 2009). Benefits in the use of simulation tasks in this kind of 3D virtual learning environments range from cost saving to efficiency and security. Furthermore, the strengthening of sociability and scalability (Grimstead et al., 2005) can be far greater comparing with conventional, collaborative multi-user enabling systems.

**Fig. 1** Collaborative aircraft maintenance process in a 3D virtual learning environment

Research on K-12 and higher education has suggested that interactions in 3D3C worlds can stimulate users while producing understandings of the main subject matter (Jonassen, 2004). The characteristics of this kind of virtual environment may promote collaboration for making the work more dynamic and engaging (Reeves et al., 2008). 3D3C worlds still have the potential to support crowded online settings where hundreds of participants can reach social engagement by dynamically forming subgroups (Schneider et al., 2012). However, the lack of in-depth studies for evaluating dynamic scenarios constitutes a challenge for identifying requirements in adapting collaboration mechanisms to individuals, groups, and crowds.

## 3 The Unrealized Potential of Virtual Worlds for Learning and Training: Meta-Analysis

### *3.1 Method*

The details about the initial sample selection and review processes were presented by Correia et al. (2014), and this chapter extends the previous work by distilling conceptual evidences as meta-theoretic units of analysis. The results of this study were obtained applying a Systematic Literature Review (SLR) process based on the known guidelines (Kitchenham et al., 2009; Stapić et al., 2012). Qualitative content analysis techniques (Graneheim & Lundman, 2004; Onwuegbuzie et al., 2012) were also used as complementary approaches to extract qualitative evidences from literature. In this study, old publications and bibliometric indicators (e.g., authors' affiliation, and number of citations) were discarded from analysis. The focus relies on distinguishing what needs to be undertaken in the use and deployment of 3D3C worlds for collaborative learning and training.

In the first stage, keywords and related terms were introduced and 156 studies were retrieved in accordance to the total number of citations provided by Google Scholar's citation index. This process was complemented by a snowball sampling approach to identify potential studies from references. In the next phase, three duplicated papers were removed. The lack of quantifiable metadata for two studies was also an exclusion criterion. Subsequently, 102 studies were removed due to the inadequacy of their subjects for a meta-analysis focused on 3D3C worlds and their unsolved gaps. The remaining sample is constituted by a set of 49 publications. From this corpus, a wide range of studies related with learning (e.g., K-12, higher education) was identified.

Limitations and possibilities for research were initially extracted as meaning units (or textual excerpts) from which a condensing technique was used. As explained by Graneheim and Lundman (2004), a meaning unit can be understood "as the constellation of words, sentences or paragraphs containing aspects related to each other through their content and context". A condensed meaning unit is a description close to the text, and a category is “a group of content that shares a commonality” (Krippendorff, 1980), including sub-categories at varying levels of abstraction. Creating themes is a way to link the underlying meanings together in categories. A total number of 161 condensed meaning units, 48 categories, 11 sub-categories, and 10 themes were clustered using a method similar to Jacovi et al.’s (2006) methodological approach. A refined, meta-synthesis integrating qualitative evidences from a total of 49 publications (see Table 1) summarizes the raw data extracted by meaning unit, topic/category, and theme.

## *3.2 Three-Dimensional Immersive Virtual Learning Environments*

Suggestions for future research on the use of 3D3C worlds in learning as presented by Hew and Cheung (2010) are mainly related with exploiting improvements to previous studies, doing longitudinal studies, exploring the attributes/affordances of virtual worlds, examining sociocultural factors, and studying the use of avatars (e.g., gender analysis). Furthermore, Jarmon and colleagues (2009) claimed attention for virtual world teaching and experimental learning by considering the learning curve and the current limitations in single case studies (e.g., few graduate students from distinct academic disciplines). In the meantime, Duncan et al. (2012) indicated the proposal of finely-grained classification models and surveys, better mechanisms for monitoring student learning, the development of immersion technology (e.g., 3D haptic input equipment), the study of in-world behavior and course design, the transition of in-world skills to the real world, and the inclusion of social, minority or disabled groups. In addition, Dalgarno and Lee (2010) explored the ‘learning affordances’ of 3D virtual environments (e.g., visual realism), while Barbour and Reeves (2009) stressed unsolved challenges for institutions, including but not limited to high start-up costs, student readiness and retention, accreditation, and universal access. Ultimately, Morgado (2013) summarized a set of current technological challenges faced by educators and organizations on employing virtual worlds in education.

Concerning the empirical research on the educational applicability of virtual reality, a 10-year critical review (Mikropoulos & Natsis, 2011) suggested the development of more studies incorporating intuitive interactivity and settings that use immersive virtual environments. They also pointed the importance of reporting positive results on users’ attitudes and learning outcomes in addition to the characteristics and features of virtual reality (e.g., immersion, and sense of presence). A key challenge discussed by researchers such as Inman et al. (2010) relies on the use and adoption of Second Life in K-12 and higher education, comprising the study of participants’ affective domain (e.g., learner attitudes and feelings regarding the use of virtual environments as educational learning environments), learning outcomes, and social interaction (e.g., use of communication features associated with 3D

**Table 1** Overview of qualitative content analysis

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Hew and Cheung (2010) | Enhancing descriptive studies by providing a rich, thick description of the methodology, including the duration of the study, inter- and intra-observer agreement reliability, and effect sizes so that findings can be adequately interpreted. | Qualitative research design | 1 |
| | Complementing prior studies which usually lacked a control group, uncontrolled variables (e.g., instructional strategy used), and participants with no previous correct notions about socially desirable answer. | Qualitative research design, Sampling | 1 |
| | Doing longitudinal studies (>1 year) examining not only whether students' and teachers' perceptions of virtual worlds undergo change but also whether there are any detrimental effects of using virtual world environments over a long period of time. | Qualitative research design, Long term studies | 1 |
| | Exploring the influence of 3D avatars on online perceptions, including androgyny, anthropomorphism, credibility, homophily, and users' likelihood. | Use of avatars | 2 |
| | Examining unique attributes/affordances of virtual worlds (e.g., immersion in the 3D learning content and context, and interaction with the objects in the environment). | Attributes/affordances of virtual worlds | 3 |
| | Studying the influence of sociocultural factors and country contexts. | Social and cultural contexts | 2 |
| Jarmon et al. (2009) | Gathering data about the students' levels of technical ability in Second Life prior to the educational activity, and measuring what impact the background of a student may have had on their final assessment of learning in Second Life. | Learning curve | 4 |
| | Understanding the instructional use of 3D virtual worlds, and expanding experiential learning opportunities (e.g., studying how experiential project-based collaborative activity may be applied in other instructional contexts using virtual worlds). | Educational models and activities | 5 |
| | Filling the limitations of single case studies with one graduate course and semester in length, and few graduate students from different academic disciplines. | Qualitative research design, Long term studies, Sampling | 1 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Anstadt et al. (2011) | Reducing the learning curve in the ever-expanding world of virtual reality and computer-mediated interaction. | Learning curve | 4 |
| | Considering users with developmental and physical disabilities. | Accessibility | 6 |
| | Investigating the relationship between users' virtual lives and their real lives, including what role accepted educational institutions play in online interaction and learning. | Virtual life vs. real life, Institutional role | 2<br>5 |
| | Coping with data collection limitations in virtual worlds (e.g., maintaining participant confidentiality). | Qualitative research design, Data collection | 1 |
| | Discovering how strong the influence of social mores, norms and laws are in internet-based virtual realities (e.g., Second Life) with special consideration for ethical demands of practice, including issues of safety, prevention, and mandatory reporting. | Ethical and equity issues | 7 |
| | Understanding social learning and community mentality which can affect a moral attitude change and encourage negative deviant behavior such as computer hacking. | Ethical and equity issues | 7 |
| Duncan et al. (2012) | Improving the way people use virtual worlds with the development of immersion technology like 3D haptic input equipment (e.g., video helmet, gloves, etc.), motion detection and interaction hardware and software (e.g., Kinect), and higher speed broadband and graphics cards which can reduce the lag and downtime in Second Life. | Usability, Technical issues, Haptics, Motion capture, Connectivity, Graphics | 2<br>3 |
| | Understanding in-world behavior can help develop the educational use of virtual worlds. | User behavior | 2 |
| | Performing research to find the most suitable learning theory and applicable strategy for in-world course design and practice. | Learning theories and strategies | 5 |
| | Monitoring student learning with better mechanisms developed to ensure that students have effective learning practices and that they are measured accordingly, given the known research issues of cohort analysis and observational difficulties. | Assessment and evaluation methods, Learning theories and strategies | 5 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Addressing inclusion and accessibility issues since the use of virtual worlds for education should not disadvantage particular social, minority or disabled groups. | Inclusion, Accessibility | 6 |
| | Developing suitable educational activities, learning environments, supporting technologies, revised learning theories, and experimental and verifiable evaluation practices. | Educational models and activities, Learning theories and strategies | 5 |
| | Addressing the need for both finely grained categorical work and holistic approaches to research and practice in virtual education, encompassing multiple taxonomic units. | Assessment and evaluation methods | 1 |
| | Providing fine-grained surveys demonstrating changing trends based on technology availability, speed and cost, the requirement for geographically separated teaching and hopefully a more inclusive approach to all age and social groups and physical abilities. | Qualitative research design, Research surveys | 1 |
| | Addressing contextual information taking into account its amount and display. | Contextual information | 8 |
| | Focusing the delivery of in-world skills (e.g., creating things in the virtual world) applicable to the real world by analyzing how students transfer their knowledge gained in the virtual world to real life. | Skill development, Virtual life vs. real life | 2<br>4 |
| Jäkälä and Pekkola (2007) | Identifying relevant themes and research items in virtual worlds by using qualitative methods (e.g., Grounded Theory), and proposing frameworks for classifying individual users, virtual worlds, collaboration mechanisms, and their relations in a systematic way. | Qualitative research design, Assessment and evaluation methods | 1 |
| Bailenson and Yee (2008) | Using haptic devices to measure implicit attitudes (e.g., attitudes towards different racial groups) by evaluating participants using avatars of different skin tones or ethnicities and studying the effects of being touched in a virtual environment by employing a paradigm where the touch itself is social (e.g., increasing the social status of an avatar). | Technical issues, Haptics, User behavior, Use of avatars, Presence | 2<br>3 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Davis et al. (2009) | Understanding how metaverses are different from traditional virtual collaboration and change team members' perceptions of virtuality and presence, and the relationships to foundational theories relevant for enhancing understanding of behavior, management, and technology phenomena. | Collaboration, User behavior, Virtuality, Presence | 2 |
| | Working on the design and architecture of metaverses (i.e., software and hardware). | Virtual space design | 3 |
| | Developing the ability of people to port their avatars seamlessly among different types of metaverse environments. | Interoperability | 3 |
| | Determining how individuals use specific metaverse technology capabilities to improve participation and interaction (e.g., factors affecting the avatar's appearance). | Attributes/affordances of virtual worlds, User behavior | 2<br>3 |
| | Knowing how the group attitude or group outcome may change or be enhanced in a metaverse and how do metaverse environments impact group attitude and help to build group outcomes that are synergistic. | User behavior | 2 |
| | Coping with the trade-off between scientific control and realism, inability to adequately replicate previous studies, and access to representative sample populations. | Realism, Qualitative research design, Sampling | 1<br>2 |
| | Applying measurement strategies for metaverse environments (e.g., collecting data on team and meeting behaviors) by using surveys, video, built artifacts, images, and chat. | Assessment and evaluation methods | 1 |
| | Reducing the high learning curve associated with metaverse technology by augmenting the ease with which people enter and become comfortable in virtual worlds. | Learning curve | 4 |
| | Overcoming restriction and scheduling difficulties of the synchronous avatar interaction, and exploiting how artifacts might be used for handing-off interim tasks asynchronously. | Synchronicity | 2 |
| | Investigating how teams balance in-world and out-world processes, and what tasks are amenable to metaverse technology capabilities. | User behavior, Virtual life vs. real life | 2 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Understanding the adoption and diffusion of metaverses in everyday use. | User acceptance, Ubiquity | 2 |
| | Filling the lack of instructional design and faculty development programs with distance learning strategies. | Institutional role, Learning theories and strategies | 5 |
| Phillips and Berge (2009) | Overcoming the extensive limitations in the use of teledentistry regarding insurance coverage, licensure, malpractice, and privacy since real patient data may be misdiagnosed due to medical error or lost through transmission of data. | Healthcare, Security | 3<br>6 |
| | Investigating the users' experiences of leisure gaming technology for explicit medical training purposes. | Games, Healthcare | 6<br>9 |
| Creutzfeldt et al. (2010) | Solving technical issues such as bandwidth, hardware, firewalls, downtime and lag, as well as usage problems such as navigation, object creation and avatar manipulation. | Technical issues, Connectivity, Security, Navigation, Use of avatars, Object creation and manipulation | 2<br>3 |
| Warburton (2009) | Addressing the management of virtual identities, including the ways users grapple with the fluidity and playfulness. | Virtual identity | 2 |
| | Improving digital and cultural literacies by coping with cultural issues such as the difficulty of finding, developing a sense of belonging to, and becoming an active participant of an in-world community, as well as the need to become comfortable and familiar with the codes, norms and etiquette rules of the virtual world. | Social and cultural contexts, Ethical and equity issues | 2<br>7 |
| | Understanding the links between immersion, empathy and learning more fully, and developing design skills that can be used productively to exploit virtual spaces. | Immersion, Empathy, Virtual space design, Skill development | 2<br>3<br>4 |
| | Addressing collaboration issues that have to do with the challenges in cooperation and co-construction within a virtual world, and the minimal social networking tools and functions available. | Collaboration, Object creation and manipulation, Social media | 2<br>3<br>9 |
| | Designing and implementing learning activities and resources that make use of the technology in pedagogically sound ways, including time issues and the associated workload impositions on educators. | Educational models and activities, Synchronicity, Workload | 2<br>5 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Considering economic issues, including the cost of purchasing land, uploading images and textures, buying in-world objects/tools, and employing skilled people to perform building and scripting tasks. | Economic models | 10 |
| | Addressing the problem of standardization, specifically the lack of open standards and interoperability between virtual world platforms, which limits educators and institutions to transfer resources. | Standardization, Interoperability | 3 |
| | Scaffolding persistence and social discovery issues. | Persistence, Sociability | 2 |
| Inman et al. (2010) | Developing more safe and secure environments for all students in K-12 through the collaboration between researchers and educators. | Security | 3 |
| | Collecting data from within the virtual worlds since their ethnographic research possibilities are endless. | Qualitative research design, Data collection | 1 |
| Wimpenny et al. (2012) | Realizing conceptualizations within groups of students concerning the mutability of the relationship between digital games, social media and virtual worlds. | Games, Social media | 9 |
| Mikropoulos and Natsis (2011) | Performing studies incorporating intuitive interactivity and settings that use immersive virtual environments reporting positive results on users' attitudes and learning outcomes. | Immersion, User behavior, Learning outcomes | 2<br>5 |
| | Studying characteristics of virtual reality (e.g., immersion) and features such as the sense of presence (e.g., perceptual features, individual factors, content characteristics, and interpersonal, social and cultural contexts). | Immersion, Presence, Social and cultural contexts | 2 |
| Parsons and Cobb (2011) | Developing robust and usable technologies that can really make a difference in real world classrooms and educational contexts, and testing the relevance and applicability of virtual reality for children on the autism spectrum. | Healthcare, Autism spectrum | 6 |
| | Answering questions about the nature of the representation itself. | Use of avatars | 2 |
| Bellani et al. (2011) | Using virtual reality tools for habilitation in autism helping caretakers and educators to enhance the daily life social behaviors of autists. | Healthcare, Autism spectrum, Inclusion, Sociability | 2 |
| | Investigating how newly acquired skills are transferred to real world and whether virtual reality may impact on neural network sustaining social abilities. | Skill development, Virtual life vs. real life, Sociability | 2<br>4 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Dalgarno et al. (2011a) | Taking accurate pictures of the 'state of play', including current, past and planned tools at various institutions, so as to help direct research, development and use, as well as compiling an annotated bibliography of published research into, and evaluations of, 3D immersive virtual worlds in higher education. | Qualitative research design, Research surveys | 1 |
| Wright and Madey (2009) | Refining past surveys of technologies for building virtual environments with different and updated variables. | Qualitative research design, Research surveys | 1 |
| Messinger et al. (2008) | Understanding how standards of social behavior are evolving in virtual worlds comparing with the physical world, evaluating the influence of behaviors and attitudes learned in virtual worlds on real-world settings. | User behavior, Virtual life vs. real life | 2 |
| | Approaching regulation in virtual worlds, including social values and norms implied in the process as well as their influence on aspects such as creativity and productivity. | Regulation, Ethical and equity issues | 3<br>7 |
| | Understanding the influence of factors such as the monetary system in virtual worlds, nature of the platform, and forms of interaction allowed (e.g., synchronous, and asynchronous) on people's behavior, identifying how they differ in meeting people's information needs, stimulating social interaction, or engendering trust. | Economic models, Technical issues, Synchronicity, User behavior, Sociability, Contextual information | 2<br>3<br>8<br>10 |
| | Identifying how the appearance of an avatar instructor be designed. | Use of avatars | 2 |
| | Discovering if different platforms are more or less conducive to self-governance. | Governance | 2 |
| | Studying demographics, psychographics, geographic characteristics, membership sizes, and participation levels of various virtual worlds. | Quantitative research design, Social and cultural contexts | 1<br>2 |
| | Verifying how virtual worlds will support themselves with a single up-front fee, periodic subscription payments, advertising, pay-as-you-go extras, or sales of ancillary products. | Economic models | 10 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Schmeil and Eppler (2008) | Providing additional patterns, classification approaches, and well-grounded guidelines in virtual environments. | Assessment and evaluation methods | 1 |
| | Performing on-going revisions of the current classification models, and developing scientific proof to help researchers, designers and practitioners to assess a 3D collaboration and learning scenario in terms of its scope and benefits. | Assessment and evaluation methods, Collaboration | 1<br>2 |
| | Executing experimental comparisons of collaboration tasks in 3D3C worlds against corresponding tasks in text-based virtual worlds and real life collaboration settings. | Collaboration, Virtual life vs. real life | 2 |
| | Investigating the question of which theories (e.g., the actor-network theory, Gibson's theory of affordances, and the cognitive scaffolding theory) help to explain 3D interaction for collaboration and learning. | Learning theories and strategies, Collaboration | 2<br>5 |
| | Identifying enhancements needed to make a 3D virtual world a really useful environment for serious distributed collaborations. | Attributes/affordances of virtual worlds, Collaboration | 2<br>3 |
| Schmeil and Eppler (2010) | Proposing more frameworks to provide indications about the possible value added by collaboration patterns in virtual environments. | Qualitative research design, Collaboration | 1<br>2 |
| | Using controlled online experiments and in-situ participatory observation in institutions. | Qualitative research design | 1 |
| Otto et al. (2006) | Addressing effective haptic implementations for immersive projection technology, as well as studying the role of gaze, facial expressions and body postures during concurrent object interaction. | Technical issues, Haptics, Motion capture, Immersion | 2<br>3 |
| De Freitas (2008) | Analyzing how the license-fee based worlds will survive against the open source ones. | Economic models | 10 |
| | Providing a framework for ongoing work concerning the tension between participation, learner control, educational standards and quality assurance, and accurate benchmarking metrics for evaluation and validation. | Educational models and activities, Assessment and evaluation methods | 1<br>5 |
| | Testing the real learning opportunities of multiplayer role play games and mirror worlds. | Games | 9 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Creating more engaging, personalized and student-centered learning experiences, especially for hard-to-reach and unmotivated learner groups and those studying at a distance. | Educational models and activities | 5 |
| | Empowering learners to construct their own spaces, content and activities, facilitating cross-disciplinary collaborative research and learning initiatives as well as mixing or 'blending' virtual and real spaces and experiences by using tools such as SketchUp and 3ds Max. | Virtual space design, Object creation and manipulation, Collaboration, Virtual life vs. real life | 2<br>3 |
| | Providing support for learners with disabilities or mobility issues. | Accessibility | 6 |
| | Considering access control and the need for broadband connectivity, the development of open standards, and the provision of support for practitioners in the form of guidelines, case studies and implementation models. | Technical issues, Connectivity, Standardization, Access control | 3 |
| Salmon (2009) | Retrieving teachers' visions about the potential of virtual worlds (especially in the teaching of history and science). | Qualitative research design | 1 |
| | Integrating learning technologies as a prospect to create effective and customized 3D virtual classrooms, and understanding how to transfer pedagogical concepts from other electronic environments to frame group development and group working. | Interoperability, Educational models and activities, Virtual space design | 3<br>5 |
| Brown et al. (2011) | Testing the emergent themes of intuitiveness, ease of application, soundness, usefulness, user acceptance, and enhanced knowledge sharing ability in further, more controlled, empirical research. | Qualitative research design, User acceptance | 1<br>2 |
| | Enhancing computer-supported networked collaborative process modeling. | Collaboration | 2 |
| | Ensuring scalability to larger and more complex collaboration process scenarios. | Scalability, Collaboration | 2<br>3 |
| | Applying usability analysis in modeling interactions in order to improve their affordance for collaborative process tasks. | Usability, Collaboration | 2<br>3 |
| Prasolova-Førland (2008) | Exploiting the influence of virtual place design and other factors on the suitability of 3D virtual worlds in educational settings, and discovering how they could be analyzed in a systematic way, place metaphors typically used, and beneficial design features. | Virtual space design | 3 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Hasler et al. (2009) | Studying the physical environment from which team members access the environment. | Virtual life vs. real life | 2 |
| | Creating a research agenda focused on behavioral indicators of high- and low-performing teams, sociability factors, and usability toward a theoretical foundation on collaboration in 3D virtual worlds. | Qualitative research design, Research surveys, User behavior, Sociability, Usability, Collaboration | 1<br>2<br>3 |
| | Proposing an automated behavioral tracking approach towards the systematic analysis of group interaction processes. | User behavior, Assessment and evaluation methods | 1<br>2 |
| Pinkwart and Olivier (2009) | Exploring possible classes of group work and project-based learning that can be enhanced through 3D3C worlds' technology by investigating the risks and chances of new options for collaborative work and learning contexts. | Collaboration, Educational models and activities, Learning theories and strategies | 2<br>5 |
| | Advancing the recognition of gestures and facial expressions of the user and projecting them into the virtual world through the avatar, and exploiting the full potential of this interaction technique through ongoing research on collaboration dynamics. | Motion capture, Use of avatars, Collaboration | 2<br>3 |
| | Investigating the adoption of 3D3C worlds in organizations (e.g., training staff). | Organizational contexts | 9 |
| | Exploring requirements for 3D virtual worlds to make inroads into the everyday work practices of users, probably one of the most crucial aspects to deal with it is privacy. | Security | 3 |
| Montoya et al. (2011) | Examining the content of communications and the relationship with performance given the social relational affordances offered by 3D virtual worlds (e.g., team transcripts could be content coded to reveal the proportion of communications devoted to task-related interactions conveying ideas, decision-making and social/relational exchanges). | Qualitative research design | 1 |
| | Considering inter- and intra-organizational uses including collaborative virtual teamwork. | Collaboration, Organizational contexts | 2<br>9 |
| | Performing systematic and foundational research that examines the impact of 3D virtual worlds on team behaviors and ultimately performance-related outcomes. | Qualitative research design, User behavior | 1<br>2 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Understanding the relative importance of affordances on both team processes and outcomes, particularly as they may vary by 3D platform. | Attributes/affordances of virtual worlds | 3 |
| | Examining how communication technology use is related with aspects of mediated team collaboration. | Collaboration | 2 |
| | Exploring the learning curve associated with virtual worlds, which can help managers to understand start-up costs needed to support a virtual team into a 3D platform. | Learning curve | 4 |
| | Performing longitudinal research engaging real teams in the context of real projects. | Qualitative research design, Long term studies | 1 |
| Wallace et al. (2009) | Focusing on affiliativeness and sociability as an interesting step in the investigation of collaboration in virtual worlds for education, and examining other personality traits related with collaboration in virtual worlds between avatars of different ethnicities, species and other forms, where further studies could examine such facets of personality as emotional empathy, arousal and sensation seeking, affect and emotions. | Collaboration, Sociability, Virtual identity | 2 |
| | Developing frameworks considering positive social attitudes of participants in distance learning environments hold toward their classmates' avatars. | Sociability, Use of avatars | 2 |
| Hansen (2008) | Using virtual simulations to teach healthcare students may be questionable until more research is conducted and educational outcomes are realized. | Healthcare, Learning outcomes | 5<br>6 |
| | Considering the time and cost involved in creating learning spaces within a virtual environment. | Virtual space design | 3 |
| | Assessing the efficiency associated with sharing text, images, and videos via an avatar versus a standard format on a computer's desktop. | Use of avatars | 2 |
| | Evaluating learning outcomes by overcoming challenges facing developers of virtual worlds and serious gaming for educational purposes (e.g., ownership of collaborative work, and certification of authorship). | Learning outcomes | 5 |
| | Determining students' satisfaction, competency, and knowledge acquisition. | Learning outcomes | 5 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Weinberg et al. (2009) | Providing evidence regarding the benefit of simulation as measured by actual patient outcomes, with the exception of resuscitation and central line placement studies. | Healthcare | 6 |
| | Filling the limitations of current simulation studies including small sample size and lack of validated instruments to measure performance. | Qualitative research design, Sampling | 1 |
| | Incorporating a scenario-based curriculum in many institutions which are unable to afford the high cost of advanced patient simulators can successfully increase provider skills and performance. | Institutional role, Skill development, Healthcare | 4<br>5<br>6 |
| Ghanbarzadeh et al. (2014) | Studying the impact of 3D virtual worlds in the education of surgeons. | Healthcare | 6 |
| | Creating specific rooms and environments in virtual worlds so students can remotely access their course materials (e.g., files, e-books, lecture captures, and presentation slides). | Virtual space design, Educational models and activities | 3<br>5 |
| | Training students and the public in first aid with 3D virtual worlds. | Learning curve | 4 |
| | Analyzing the impact of 3D virtual worlds on people's health and lifestyle, and investigating the advantages and disadvantages of applying this technology in improving healthy behaviors and extending the health culture. | Healthcare | 6 |
| | Filling the lack of research on some application areas of 3D virtual worlds in treatment in healthcare and medicine (e.g., social isolation, care of the elderly, and phobias). | Healthcare, Inclusion | 6 |
| | Applying of 3D virtual worlds in modeling, and simulating health scenarios (e.g., investigating the impact of simulated sophisticated hospital equipment on the skill-building of hospital staff). | Healthcare, Skill development | 4<br>6 |
| | Examining the impact of 3D virtual worlds on various healthcare contexts through the replication of earlier studies with larger sample sizes. | Healthcare, Qualitative research design, Sampling | 1<br>6 |
| De Freitas and Oliver (2006) | Designing frameworks that consider explicitly the use of simulations in education and guide and support the evaluation of educational software, including the context, learning theory and practice and the attributes of the learner and learner group. | Assessment and evaluation methods, Educational models and activities, Learning theories and strategies | 1<br>5 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Barbour and Reeves (2009) | Researching the factors that account for K-12 student success in distance education and virtual school environments, and performing more design research approaches than traditional comparisons of student achievement in traditional and virtual schools. | Learning outcomes, Educational models and activities | 5 |
| | Coping with high start-up costs associated with virtual schools, access issues surrounding the digital divide, approval or accreditation of virtual schools, and student readiness issues and retention issues. | Economic models, Universal access, Institutional role, Learning outcomes | 5<br>6<br>10 |
| Savin-Baden (2010) | Working on haptics, motion capture, simulation and deconstruction, merging real life and immersive virtual worlds, using photorealism in order to use one's real life face on one's avatar, and using voice and own name/identity so that the interaction between real life and avatar identity was closer. | Haptics, Motion capture, Realism, Use of avatars, Virtual identity, Virtual life vs. real life | 2<br>3 |
| Savin-Baden et al. (2010) | Allowing guidance and pedagogic structuring, and filling the lack of understanding of the location and roles of staff when teaching in immersive virtual worlds in higher education, particularly since most research is focused on how students perceive learning in such educational contexts. | Educational models and activities, Institutional role | 5 |
| | Exploiting the other dimension of the kinetic 3D nature of immersive virtual worlds, including identity work, meaning-making, and self-representation by means of a complex set of interlocking modes of communication. | Motion capture, Virtual identity | 2<br>3 |
| Dionisio and Gilbert (2013) | Developing psychological realism (e.g., sound, touch, and gestures and expressions), ubiquity of access and identity (availability of virtual worlds, and manifest persona and presence), interoperability of content and experience across virtual environments, and scalability as essential features of virtual world technology. | Realism, Ubiquity, Virtual identity, Presence, Universal access, Interoperability, Scalability | 2<br>3<br>6 |
| | Moving from a set of sophisticated but completely independent immersive environments to a massive integrated network of 3D virtual worlds or metaverse, thus establishing a parallel context for human interaction and culture. | Interoperability | 3 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Dalgarno and Lee (2010) | Documenting enhanced post-test knowledge and/or skills of students using desktop-based 3D environments over those using equivalent 2D technologies, testing if the facilitation of embodied actions and communication within a 3D MUVE lead to a greater sense of co-presence and afford learning tasks that encourage richer and/or more effective collaborative learning than is possible with 2D alternatives. | Skill development, Presence, Collaboration | 2<br>4 |
| | Studying how realistic display, smooth view changes and embodied actions contribute independently or together to spatial knowledge development, when compared to alternative static or animated images. | Realism, Spatial knowledge | 2<br>8 |
| | Identifying how the various aspects of the environment fidelity (e.g., visual realism, and refresh rate) lead to the achievement of a sense of presence, engagement, intrinsic motivation, and improved contextualization of learning (manifested through greater transfer to a corresponding real environment) in a 3D virtual learning environment. | Realism, Presence, Virtual life vs. real life | 2 |
| | Testing if spatial audio and tactile feedback leads to the achievement of a greater sense of presence and the learner's development of spatial knowledge representations in a 3D virtual learning environment. | Presence, Spatial knowledge | 2 |
| | Identifying changes to accepted design principles from established theories (e.g., cognitive load theory, dual coding theory, cognitive theory of multimedia learning) when instructional elements are presented within a 3D virtual learning environment. | Learning theories and strategies | 5 |
| | Designing learning tasks to be carried out within a 3D virtual learning environment to meet specific, desired educational outcomes (e.g., content knowledge in particular subject domains, and generic skills such as teamwork and problem solving). | Educational models and activities, Learning outcomes, Skill development | 4<br>5 |
| | Identifying characteristics of learning tasks within a 3D virtual learning environment that will make them intrinsically motivating, and result in a high sense of presence. | Educational models and activities, Presence | 2<br>5 |
| | Discovering how important is suspension of disbelief to the achievement of both cognitive and affective learning goals. | Learning theories and strategies | 5 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Boulos et al. (2007) | Overcoming caveats and workarounds of 3D virtual worlds, including Internet addiction, gambling, violence, pornography, trust, identity and privacy issues, copyright issues, health information quality and quackery issues, vandalism, and the need to master new skills depending on user role (e.g., ordinary resident, learner, educator, and builder). | Ethical and equity issues, Security, Contextual information, Skill development | 3<br>4<br>7<br>8 |
| | Supporting older people and people with physical disabilities, and helping them combat social isolation and loneliness with 3D virtual worlds may pose potential user interface, 3D navigation/accessibility issues. | Inclusion, Accessibility, Navigation | 3<br>6 |
| | Using 3D virtual worlds for supporting medical and health education. | Healthcare | 6 |
| | Identifying educational and library-related possibilities explored in various settings/scenarios and carefully researched, refined and evaluated to document best practices, as well as characterizing the pitfalls that are to be avoided before they can be extensively used in daily teaching and learning activities. | Educational models and activities, Learning theories and strategies | 5 |
| De Freitas et al. (2010) | Exploiting interactivity and immersion as relatively under-researched areas, designing experiments in the representational dimension. | Interactivity, Immersion | 2 |
| | Engaging more learners on structuring learning activities, and providing greater support in advance of trialing. | Learning theories and strategies | 5 |
| | Providing more rigorous frameworks and metrics for supporting future efficacy studies. | Assessment and evaluation methods | 1 |
| Dalgarno et al. (2011b) | Addressing technological problems, limitations and success factors such as bandwidth, firewalls and other IT policy issues, hardware requirements, and audio. | Technical issues, Connectivity, Ethical and equity issues | 3<br>7 |
| | Solving problems related with support, funding and time (e.g., time commitment, cost and funding, management support, and resources). | Economic models, Management | 10 |
| | Coping with usability and familiarity concerns, including student user familiarity and learning curve, academic user familiarity and learning curve, and general user familiarity and usability of software. | Usability, Learning curve | 3<br>4 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Solving equity related and ethical problems, limitations and success factors. | Ethical and equity issues | 7 |
| | Analyzing student acceptance, academic staff acceptance, and general acceptance concerning the use of virtual worlds. | User acceptance | 2 |
| | Approaching management and planning issues, including planning for learning (e.g., content, outcomes, and timelines), design and development of the environment, people synchronization issues, continuity as subject is revised and/or teaching staff changed, need for workshops, meetings, training, and need to collaborate with others. | Management, Learning theories and strategies, Learning outcomes, Virtual space design, Synchronicity, Institutional role, Collaboration | 2<br>3<br>5<br>10 |
| Allison et al. (2012) | Filling the lack of features provided by OpenSimulator and Second Life by coping with non-exhaustive challenges such as management guidance for educators (e.g., training for virtual world management), network infrastructure, 3D Web, and programmability. | Management, Technical issues, Connectivity | 3<br>10 |
| Callaghan et al. (2009) | Integrating virtual learning environments and virtual worlds to harness relative strengths of each platform (e.g., the course management features of virtual learning environments and the immersive/highly interactive nature of virtual worlds) can create engaging learning experiences for students, overcoming overheads in setting up, configuring and maintaining an own server and the final decision about which platform to use would be down to individual choice and requirements. | Interoperability | 3 |
| Konstantinidis et al. (2010) | Integrating Sloodle and OpenSimulator platforms for supporting collaborative learning scenarios in a broad and simplified sense, overcoming scientific challenges (e.g., the ability of assessing or validating learning in formal contexts), pedagogical interoperability challenges (e.g., identifying and combining complementary and compatible pedagogies), and technical challenges (e.g., integration of 2D and 3D educational tools, resulting in an efficient, accessible and accomplished system, and bridging the different systems, defining standards, and envisaging innovative interfaces). | Interoperability, Collaboration, Technical issues | 2<br>3 |
| Allison et al. (2011) | Broadening virtual worlds in terms of business models and programmability to support open learning. | Economic models, Technical issues | 3<br>10 |

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**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Allison, Miller, Sturgeon, Nicoll, and Perera (2010) | Exploiting the validity of online identity, privacy of personal work from other students, easy accessibility to coursework for markers, provenance of authorship, and a reliable submission mechanism which constitute security issues associated with the management of a credit-bearing coursework. | Virtual identity, Security, Access control, Universal access | 2<br>3<br>6 |
| | Creating innovative, interactive learning environments, and engaging students in coursework assignments for overcoming social and technical drawbacks such as (1) annual recurrent funding to rent land, (2) land cost divided into parcels for individual students coursework, (3) distant servers with poor Quality of Service unblocked by institutional firewalls, (4) presence of "adult content" and an age barrier at 18, (5) inability to make copies of content outside of Second Life, and (6) permissions model making submission of coursework unreliable. | Virtual space design, Technical issues, Economic models, Access control | 3<br>10 |
| Dede (2009) | Discovering to what extent does good instructional design for immersive environments vary depending on the subject matter taught or on the characteristics of the learner, and for what types of curricular material is full sensory immersion important. | Educational models and activities, Immersion | 2<br>5 |
| | Exploring the ability of the successes of one's virtual identity in immersive environments to induce greater self-efficacy and educational progress in the real world. | Virtual identity, Learning outcomes, Virtual life vs. real life | 2<br>5 |
| | Discovering optimal blend of situated learning in real, augmented, and virtual settings, and identifying which insights about bicentric frames of reference can generalize from immersive environments to pedagogical strategies in face-to-face settings. | Learning theories and strategies | 5 |
| Hendaoui et al. (2008) | Simulating and integrating components of a real-world classroom (teachers' and students' physical presence, classroom, and video and voice capabilities, among other things) which leads to research issues related with a possible transition from e-learning to v-learning, virtual space design, lecturers' roles, assessment of learning outcomes, instructor's avatar design and appearance, and adoption and use of social virtual worlds as teaching environments. | Virtual life vs. real life, Presence, Virtual space design, Learning outcomes, Use of avatars, User acceptance, Assessment and evaluation methods | 1<br>2<br>3<br>5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Anstadt et al. (2013) | Investigating (1) technological infrastructures for supporting the future metaverse, (2) standards and/or 3D protocols (e.g., OpenGL, Direct 3D) for social virtual worlds, (3) evolution of clients (e.g., by integrating head-mounted displays for enhanced 3D experiences), (4) connection of mobile devices and Web sites with social virtual worlds, (5) development of easy-to-use and powerful applications to build content for social virtual worlds, (6) interoperability between heterogeneous social virtual worlds, (7) communication protocols and standards, (8) ability to run the own social virtual world servers and interaction with other servers, (9) security problems and tools such as antispam, antivirus, and antispyware into social virtual worlds, (10) dynamics of the virtual worlds, and (11) emergent behavior. | User behavior, Technical issues, Standardization, Connectivity, Interoperability, Security | 2<br>3 |

Legend:

| Theme | Description | Topic/category |
|---|---|---|
| #1 | Research methods, theories and models, and user studies | Qualitative research design (Sampling, Long term studies, Data collection, Research surveys), Assessment and evaluation methods |
| #2 | Sociological concerns | Social and cultural contexts, Virtual life vs. real life, User behavior (Use of avatars, Virtual identity), Presence, Collaboration, Synchronicity, Virtuality, Realism, User acceptance, Ubiquity, Immersion, Workload, Persistence, Sociability, Governance, Interactivity |
| #3 | Technical characteristics and attributes | Usability, Attributes/affordances of virtual worlds, Technical issues (Haptics, Motion capture, Connectivity, Graphics), Virtual space design, Interoperability, Security, Regulation, Access control, Navigation, Object creation and manipulation, Standardization, Scalability |
| #4 | User familiarity and expertise | Learning curve, Skill development |
| #5 | Educational settings | Educational models and activities, Learning theories and strategies, Learning outcomes, Institutional role |
| #6 | Healthcare and universal design | Healthcare (Autism spectrum), Accessibility, Inclusion, Universal access |
| #7 | Ethics | Ethical and equity issues |
| #8 | Context and awareness | Contextual information, Spatial knowledge |
| #9 | Application areas | Games, Social media, Organizational contexts |
| #10 | Monetary and management issues | Economic models, Management |

virtual environments). Complementarily, they also suggested the creation of more safe and secure environments for students in K-12, and the use of ethnography to collect and analyze data. Hence, a review undertaken by Savin-Baden et al. (2010) emphasized pedagogy, staff role, and digital literacies. The authors described issues concerned with identity work, meaning-making, self-representation, and location and roles of staff when teaching.

Savin-Baden's (2010) study on staff experiences of learning and teaching in immersive worlds "introduced issues relating to identity play, the relationship between pedagogy and play and the ways in which learning, play and fun were managed (or not)". The interaction between virtual world and real life was also addressed with challenges in haptics, motion capture, simulation and deconstruction, photorealism, and identity. Nevertheless, socio-political impacts of virtual world learning on higher education were exploited by Wimpenny et al. (2012), and three dominant frames of reference have appeared: institutional space and ownership, disciplinary learning, and games and gaming media. Moreover, a scoping guide for serious virtual worlds (De Freitas, 2008) discussed challenges related with the survivability of license-fee based worlds against open source platforms, the co-construction of virtual spaces, activities and content, the support for learners with disabilities or mobility limitations, and the creation of accurate benchmarking metrics for assessment and validation.

The use of virtual worlds in education was also studied from an OpenSimulator perspective (Allison et al., 2012), introducing challenges concerned with network infrastructure, management guidance, 3D Web, and programmability. Although 3D virtual learning environments are able to support teaching and learning in educational contexts, their presentation layer are highly restrictive (Callaghan et al., 2009), and more alternatives integrating virtual worlds with virtual learning environments (e.g., Sloodle) are required to create engaging learning experiences for students (Konstantinidis et al., 2010). Nonetheless, simulating and integrating the components of real-world classrooms, as well as adopting and using social virtual worlds as teaching environments were indicated as research goals (Hendaoui et al., 2008). The abilities of virtual worlds for engaging students in open learning were tested by Allison et al. (2011), despite their restrictiveness in terms of business models and programmability, while land cost, quality of server providers, age filter, authorship and privacy were also considered as challenges that must be addressed (Allison et al., 2010). As technology evolve to support learning specificities, more studies are needed regarding the abilities, strengths and preferences of immersive media, as well as the suitability of instructional designs to varied types of immersive mediums (Dede, 2009).

## *3.3 Sociological Perspectives on 3D3C Worlds in Learning*

The seminal ethnographic work presented by Castronova (2001) dawned the interest on the use of qualitative data collection methods for virtual worlds research, considering interactivity, physicality, and persistence as distinguishing features. Subsequently, Castronova and Falk (2008) approached virtual worlds as Petri dishes for the social and behavioral sciences. A typology of virtual worlds was presented by Messinger et al. (2008), including the purpose, place, platform, population, and profit model. According to the authors, emergent features may become worth incorporating into such kinds of classification schemes. Furthermore, more research is needed on understanding standards of social behavior, attitudes learned in virtual worlds, influence of factors such as the nature of platform on people's behavior, regulation (e.g., social values and norms), avatar appearance, self-governance, etc. Nonetheless, economic concerns (e.g., periodic subscription payments), guidelines and demographics might also be studied. Anstadt et al. (2011) recognized a need for considering users with developmental and physical disabilities, the relationship between virtual and real life contexts, institutional roles, and ethical demands of practice (e.g., safety, and prevention). In addition, Bailenson and Yee (2008) mentioned the use of haptic devices as possible instruments to measure implicit attitudes towards aspects such as ethnicities or skin tones, while immersive 3D virtual worlds were addressed by Otto et al. (2006) taking into account their suitability for supporting closely coupled collaboration.

Davis et al. (2009) characterized the use of virtual worlds for virtual team collaboration, considering the virtual world itself, people/avatars, technology capabilities (communication, rendering, interaction, and team process), behaviors (coordination, trust, role clarity, and shared understanding), and outcomes (perceived quality, member support, self-image, cultural synchronicity, intent to immerse, deception, and reconnect anxiety) as elements of a conceptual model for virtual worlds research. The transition of newly acquired skills from virtual to real world and the impact of virtual reality on the neural network sustaining social abilities were indicated as current challenges. Some scholars believe that there is a need to cope with virtual identities, digital and cultural literacies, immersion, empathy and learning, design skills, collaboration, economic concerns (e.g., cost of purchasing land), social presence and social networks, standardization, and scaffolding persistence and social discovery (Warburton, 2009). Similarly, interactivity and immersion were also considered under-researched areas in the representational dimension (De Freitas et al., 2010).

A systematic description structure of collaboration patterns in 3D virtual environments was proposed by Schmeil and Eppler (2008), including usage situations, objective, number of participants, interaction intensity, typical duration, required artifacts, avatar actions, risks, and design effort. The authors advocate the promotion of new frameworks and on-going revisions in classification models, experimental comparisons of collaboration tasks in 3D virtual worlds, text-based virtual worlds, and real life collaboration settings, as well as theories explaining 3D interaction in collaboration and learning scenarios. Complementarily, Schmeil and Eppler (2010) suggested a systematic framework which "organizes the necessary elements for the design and implementation of collaboration patterns in virtual worlds", claiming for contributions on the use of controlled on-line experiments and in-situ participatory observation within organizations. Computer-supported networked collaborative process modeling was considered by Brown et al. (2011) as a challenge for researchers in terms of testing emergent themes (e.g., intuitiveness, user acceptance, and ease of application), ensuring scalability to larger and more complex collaboration process scenarios while applying usability analysis in modeling interactions.

Place metaphors used in 3D virtual learning environments were previously addressed (Prasolova-Førland, 2008). Hasler et al.'s (2009) conceptual framework and research agenda focused on behavioral indicators of virtual teamwork (i.e., form and content of team interaction, individual level effects, and intra- and inter-group effects), sociability factors (perceived presence, social conventions, emerging roles, and relationship formation), and usability factors (perceived usability, collaboration tools, communication mode, and support facilities). The link between spatial and visual characteristics, collaborative behaviors, and virtual teamwork in 3D3C worlds was explored by Montoya et al. (2011), while Wallace et al. (2009) studied the self-representation with human and non-human avatars concerning the willingness to collaborate in virtual worlds.

### *3.4 Immersive Virtual 3D Healthcare Learning Environments*

Considering the application of 3D virtual worlds in healthcare, Phillips and Berge (2009) reported the use of teledentistry regarding insurance coverage, licensure, malpractice, and privacy. Creutzfeldt et al. (2010) claimed for solving technical troubles (e.g., bandwidth, downtime, and lag) and usage problems such as navigation, object creation and handling, and avatar manipulation. A literature review on three-dimensional healthcare learning environments (Hansen, 2008) suggested a need for empirical research about the pedagogical outcomes and advantages of this technology taking into account the time and cost involved in creating appropriate learning spaces within a 3D virtual environment. The use of simulation as a training and assessment tool in medical education (e.g., lethal events in pediatrics such as trauma and respiratory arrest) was approached by Weinberg et al. (2009) in the form of challenges and features for human patient simulators, including but not limited to monitoring blood pressure and programmable clinical scenarios.

An analysis on the use of 3D virtual environments in healthcare (Ghanbarzadeh et al., 2014) provided insights about the need for studying the impact of this technology in the education of surgeons, improving healthy behaviors and filling the lack of research on application areas such as social isolation, care of the elderly, and phobias. In addition, Boulos et al. (2007) also indicated challenges in medical and health education, including Internet addiction, gambling, violence, identity, privacy, copyright, trust, and pornography. Parsons and Cobb (2011) presented some advantages and benefits of virtual reality in social and life skills training for children on the autism spectrum, providing evidence on the nature of representation and the lack of robust and usable technologies that can enhance real world educational contexts. Moreover, Bellani et al. (2011) also analyzed the use of virtual reality for habilitation in autism, helping caretakers and educators to enhance the daily life social behaviors of autists.

### *3.5 Technical Barriers and Empirical Research on 3D Learning Ecosystems*

A comprehensive survey performed by Dionisio and Gilbert (2013) identified psychological realism, scalability, interoperability, identity, and ubiquity of access across virtual environments as central features of virtual world technology. A vast number of limitations related with technology (e.g., bandwidth, audio, and IT policies), time commitment, cost and funding, usability, learning curve, ethics, management support and user acceptance were discussed by Dalgarno et al. (2011a, 2011b) Finally, technological infrastructures for metaverses, standards and 3D protocols, connection of mobile devices and websites with social virtual worlds, security, and interoperability were considered by Anstadt et al. (2013). Ubiquitous tracking and augmented reality have been arising as lines of further examination, while platforms such as Xj3D can be used to build and deploy 3D3C worlds. This breadth reinforces the view that an integration with collaboration tools allows increasing user's self-awareness, facilitating interaction and coordination while improving social bonds.

Qualitative methods such as ethnography and Grounded Theory are indicated as means of informing the creation of frameworks for classifying users, virtual worlds, collaboration mechanisms, and their relations in a systematic way (Jäkälä & Pekkola, 2007). In addition, more research is needed about the past, current, and planned tools at various institutions by means of surveys and annotated bibliographies considering the use of 3D immersive virtual worlds in higher education (Wright & Madey, 2009; Dalgarno et al., 2011a, 2011b). A lack of dedicated frameworks evaluating educational games and simulations in learning contexts and subject areas was mentioned as a limitation by De Freitas & Oliver (2006). In addition, Pinkwart and Olivier (2009) indicated that "a cohesive body of research is still missing" taking into account the lack of empirical research on the risks and chances of 3D virtual worlds technology within collaborative settings, the system requirements, the connection between physical and virtual objects enabling new forms of cooperation trough 'mixed reality', and the adoption of 3D3C worlds in organizations.

## 4 Discussion

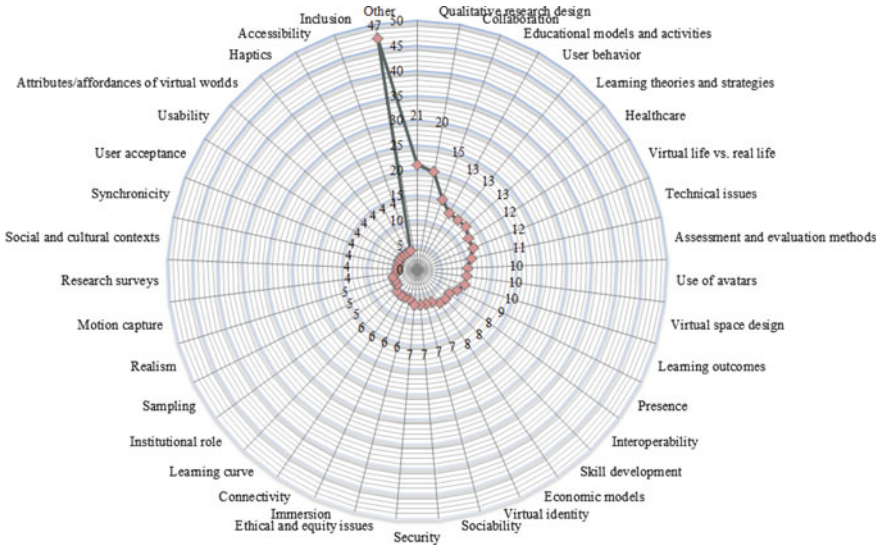
In spite of the larger number of studies, some indicators can be interpreted from a qualitative point of view. A prevalence of challenges and possibilities concerned with research study design is clearly noted, including a lack of details about the methodology, a common absence of control groups, a short length and coverage of current studies, and a need for fine-grained surveys. A second level of challenges includes the relationship between users' virtual and real lives, technical issues (e.g., bandwidth, downtime and lag, and haptics), and educational models and activities. Furthermore, collaboration is also a topic of intensive research, including issues such as object co-creation within a virtual world. Other relevant aspects include but are not limited to assessment and evaluation methods (e.g., classification models), virtual space design, user behaviors (e.g., use of avatars), interoperability, skill development, learning theories and strategies, learning outcomes, and healthcare (e.g., autism spectrum). A distinct level of abstraction comprises issues related with sociability (e.g., daily life social behaviors of autists), security, familiarity with virtual worlds, institutional role, ethics and equity, economics, accessibility, inclusion, and synchronicity. Figure 2 represents a scheme for synthesizing research challenges and opportunities in learning through the use of 3D3C worlds.

The selection criterion used for naming the categories/topics is adopted from Dalgarno et al. (2011a, 2011b), including the number of mentions as a limitation, barrier or opportunity for research. A total of 36 main categories and 23 complementary topics (with less than four mentions) were identified. As previously mentioned, earlier studies have also proposed conceptual models and research agendas in different forms. For example, Davis et al. (2009) presented a scheme for virtual worlds research comprising technology capabilities, people/avatars, behaviors, and outcomes. Relationships between categories are not comprised in this scheme.

Each category/topic has its own constituent attributes. For instance, synchronicity can be represented by synchronous or asynchronous interaction, and such sub-categories constitute the temporal dimension of a time-space matrix (Johansen, 1988). Other examples include user behavior (which can be represented by the study of emotions, attitudes, virtual identity, use of avatars, etc.) and collaboration (e.g., environment, process, support, and functions). Furthermore, sub-functions of topics such as collaboration (e.g., instant messaging, and actor presence monitoring) can arise from a new level of abstraction. However, such abstraction requires a lot of work distilling units of analysis from large amounts of text.

### 4.1 *Research Methods, Theories and Models*

There is a lack of studies examining students' and teachers' perceptions using 3D virtual worlds (including detrimental effects) over a long period of time




| Complementary categories | | | |
|---|---|---|---|
| Long term studies | 3 | Scalability | 2 |
| Access control | 3 | Autism spectrum | 2 |
| Object creation and manipulation | 3 | Spatial knowledge | 2 |
| Standardization | 3 | Social media | 2 |
| Universal access | 3 | Organizational contexts | 2 |
| Contextual information | 3 | Virtuality | 1 |
| Games | 3 | Workload | 1 |
| Management | 3 | Persistence | 1 |
| Data collection | 2 | Governance | 1 |
| Ubiquity | 2 | Interactivity | 1 |
| Navigation | 2 | Graphics | 1 |
| | | Regulation | 1 |

**Fig. 2** Research challenges and possibilities on the use of 3D3C worlds in learning and training

(Hew & Cheung, 2010). Furthermore, classification systems are required for characterizing new scenarios. Research agendas, annotated bibliographies, and surveys of published research are also required concerning the use and acceptance of 3D immersive virtual worlds in education settings (Wright & Madey, 2009; Dalgarno et al., 2011a, 2011b). Data collection in 3D3C worlds is a current problem that can be addressed by using qualitative methods such as Grounded Theory (Jäkälä & Pekkola, 2007) and virtual ethnography (Inman et al., 2010). Some experiments have been conducted "to evaluate the use of embodied survey bots (i.e., software-controlled avatars) as a novel method for automated data collection in 3D virtual worlds" (Hasler et al., 2013). Replacing human interviewers by automated, survey bots in a virtual world involves ethical implications and needs the understanding of relations where humans might co-exist with automated entities.

### 4.2 Sociological Concerns

While exploring the influence of self-representation on online perceptions using human and non-human 3D avatars is very important, including aspects such as androgyny, anthropomorphism, credibility, and skin tones (Bailenson & Yee, 2008; Hew & Cheung, 2010), more emphasis is needed on studying aspects such as in-world behavior, implicit attitudes and motivations, sociocultural factors affecting the use of 3D3C worlds, transitions between virtual life vs. real life, collaborative learning and cooperative work endeavors, and links between immersion, empathy, and learning. Researchers have recognized the importance of understanding and evaluating concepts such as presence, virtual identity and virtuality, realism (e.g., psychological), sociability, self-governance, and interactivity.

### 4.3 Technical Characteristics and Attributes

Issues related with interoperability between different virtual world platforms and other educational tools must be further addressed (Konstantinidis et al., 2010). As noted by Kelton (2008), there is a "lack of tools for facilitating truly collaborative interactions between users in real-time". Filling the lack of features provided by OpenSimulator and Second Life can be realized by coping with challenges such as programmability and network infrastructure (Allison et al., 2012), scalability (Dionisio & Gilbert, 2013), and virtual space design (Hansen, 2008). Furthermore, working on 3D haptic implementations (e.g., video helmets), motion capture (e.g., Kinect), photorealism, simulation, and deconstruction (Otto et al., 2006; Savin-Baden, 2010; Duncan et al., 2012) can allow a closer interaction between real-life and avatar identity.

### 4.4 Educational Contexts

The challenges related with 3D virtual learning environments include the perspective that "the only students typically successful in online learning environments are those who have independent orientations towards learning, highly motivated by intrinsic sources, and have strong time management, literacy, and technology skills" (Barbour & Reeves, 2009). Learning analytics is another road of ongoing research (Duncan et al., 2012) for measuring the entire learning process and outcomes (Mikropoulos & Natsis, 2011). Furthermore, there is a need for institutional support such as faculty development programs (Davis et al., 2009). Understanding the roles educational institutions play in online interaction and learning is also critical (Anstadt et al., 2011). Suitable learning theories and strategies for in-world course practice and design must be revised and examined more carefully (Duncan et al., 2012). Simulating and integrating components of real-world classrooms such as teachers' and students' physical presence (Hendaoui et al., 2008), identifying types of curricular material for which full sensory immersion is relevant (Dede, 2009), as well as characterizing the pitfalls that are to be avoided before they can be extensively used in daily teaching and learning activities (Boulos et al., 2007) must be also addressed by researchers interested in 3D virtual worlds.

### *4.5 Healthcare and Accessibility*

The design of access technology for disabled people has presented several challenges concerned with solving real accessibility problems. Moreover, frameworks to evaluate, compare and classify such technology remain necessary since it is difficult to identify contributions, connections and gaps in this space (Bigham et al., 2011). Another set of significant contributions regards the study of virtual world education as an area of further development "for the physically and socially disadvantaged, which is lagging behind other areas of research" (Duncan et al., 2012). For example, 3D virtual spaces such as the virtual store of a supermarket can be constructed for allowing users navigate by products and ask for help using human computation features. Virtual worlds for education "should not disadvantage particular social, minority or disabled groups" and must be inclusive (Duncan et al., 2012). Social isolation is a current problem and elderly people can be engaged through several activities (e.g., physical exercise) using 3D virtual worlds and motion capture technology (Paredes et al., 2014). Digital divide is a reality in certain contexts and 3D virtual learning environments should be available to all students for getting easy access to coursework materials and submission of contributions (Allison et al., 2010). Nevertheless, autism spectrum (Bellani et al., 2011; Parsons & Cobb, 2011), recovery treatments for traumas (e.g., military), and phobias (Ghanbarzadeh et al., 2014) are some application areas of 3D virtual worlds in healthcare and medicine.

### *4.6 Additional Themes Concerned with 3D3C Worlds in Learning and Training*

Complementary categories covered in this study include user familiarity and expertise, ethics, context and awareness, monetary and management issues, and application areas. From a multidisciplinary point of view, investigating the users' experiences of leisure and serious gaming technology for explicit medical training intents (Phillips & Berge, 2009), social networking tools and functions

(Warburton, 2009), and inter-and intra-organizational contexts (Montoya et al., 2011) are some application areas of virtual worlds. The learning curve related with the perceived utility and natural use of virtual world technology is also a topic of further improvement. Ethical concerns associated with gambling, copyright, violence and privacy deserve attention (Boulos et al., 2007), context, and awareness remain topics of interesting research (Dalgarno & Lee, 2010). Broadening virtual worlds in terms of economic models (considering issues such as land cost) must be also taken seriously to support open learning using three-dimensional spaces.

## 5 Final Thoughts

This chapter presents several challenges and possibilities for research in 3D virtual worlds in learning within an open, meta-theoretic research framework. The study carried on allowed identifying healthcare contexts, K-12 research, entertainment, security, cultural influence and immersion, economic concerns, mobile and multiplayer technologies, open source platforms, gestures recognition, social behaviors, and physical interaction. By updating work in the application areas of 3D virtual worlds, this study also attempts to help a wide variety of individuals and organizations, such as practitioners, nurses, managers, hospitals, healthcare agencies, private groups, business health companies and corporations, and universities (Ghanbarzadeh et al., 2014). Such insights can be particularly useful for researchers interested in this topic to better understand the field and previous studies, helping them classify research, identify gaps in the literature, and shape the future trends.

The results of this meta-analysis show that 3D3C worlds find their place as alternative ecosystems to enhance learning and collaboration abilities between humans and computerized residents and objects. Heuristics, methods and interpretations of literature-based evidences are error prone and there is a need to reinforce the creation of research agendas and theoretical frameworks aware of the social-technical requirements of virtual worlds. In addition, this analysis needs future revisions and different perspectives on the current status of research in 3D3C worlds to reinforce an updated research basis focused on different disciplines.

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## References


Allison, C., Campbell, A., Davies, C. J., Dow, L., Kennedy, S., & McCaffery, J. P., et al. (2012). Growing the use of virtual worlds in education: An OpenSim perspective. In *Proceedings of the Second European Immersive Education Summit*.

Allison, C., Miller, A., Sturgeon, T., Nicoll, J. R., & Perera, I. (2010). Educationally enhanced virtual worlds. In *IEEE frontiers in education conference* (pp. T4F-1–T4F-6).

Allison, C., Miller, A., Sturgeon, T., Perera, I., & McCaffrey, J. (2011). The third dimension in open learning. In *Proceedings of the IEEE Frontiers in Education Conference* (pp. T2E-1–T2E-6).

Anstadt, S. P., Bradley, S., Burnette, A., & Medley, L. L. (2013). Virtual worlds: Relationship between real life and experience in Second Life. *The International Review of Research in Open and Distance Learning, 14*(4), 160–190.

Anstadt, S. P., Burnette, A., & Bradley, S. (2011). Towards a research agenda for social work practice in virtual worlds. *Advances in Social Work, 12*(2), 289–300.

Bailenson, J. N., & Yee, N. (2008). Virtual interpersonal touch: Haptic interaction and copresence in collaborative virtual environments. *Multimedia Tools and Applications, 37*(1), 5–14.

Barbour, M. K., & Reeves, T. C. (2009). The reality of virtual schools: A review of the literature. *Computers and Education, 52*(2), 402–416.

Bartle, R. A. (2010). From MUDs to MMORPGs: The history of virtual worlds. In J. Hunsinger et al. (Eds.), *International handbook of internet research* (pp. 23–39). Netherlands: Springer.

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.

Benford, S., Greenhalgh, C., Rodden, T., & Pycock, J. (2001). Collaborative virtual environments. *Communications of the ACM, 44*(7), 79–85.

Bentley, R., Hughes, J. A., Randall, D., Rodden, T., Sawyer, P., & Shapiro, D., et al. (1992). Ethnographically-informed systems design for air traffic control. In *Proceedings of the ACM Conference on Computer-Supported Cooperative Work* (pp. 123–129).

Bigham, J. P., Ladner, R. E., & Borodin, Y. (2011). The design of human-powered access technology. In *Proceedings of the International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 3–10).

Boulos, M. N. K., 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*(4), 233–245.

Brown, R., Recker, J., & West, S. (2011). Using virtual worlds for collaborative business process modeling. *Business Process Management Journal, 17*(3), 546–564.

Callaghan, M. J., McCusker, K., Losada, J. L., Harkin, J., & Wilson, S. (2009). Integrating virtual worlds & virtual learning environments for online education. In *Proceedings of the International IEEE Consumer Electronics Society's Games Innovations Conference* (pp. 54–63).

Castronova, E. (2001). *Virtual worlds: A first-hand account of market and society on the cyberian frontier* (CESifo Working Paper No. 618).

Castronova, E., & Falk, M. (2008). *Virtual worlds as petri dishes for the social and behavioral sciences* (German Council for Social and Economic Data No. 47).

Correia, A., Cassola, F., Azevedo, D., Pinheiro, A., Morgado, L., Martins, P., et al. (2014). Meta-theoretic assumptions and bibliometric evidence assessment on 3-D virtual worlds as collaborative learning ecosystems. *Journal of Virtual Worlds Research, 7*(3), 1–18.

Crabtree, A., & Rodden, T. (2008). Hybrid ecologies: Understanding cooperative interaction in emerging physical-digital environments. *Personal and Ubiquitous Computing, 12*(7), 481–493.

Creutzfeldt, J., Hedman, L., Medin, C., Heinrichs, W. L., & Felländer-Tsai, L. (2010). Exploring virtual worlds for scenario-based repeated team training of cardiopulmonary resuscitation in medical students. *Journal of Medical Internet Research, 12*(3), e38.

Dalgarno, B., & Lee, M. J. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10–32.

Dalgarno, B., Lee, M. J., Carlson, L., Gregory, S., & Tynan, B. (2011a). An Australian and New Zealand scoping study on the use of 3D immersive virtual worlds in higher education. *Australasian Journal of Educational Technology, 27*(1), 1–15.

Dalgarno, B., Lee, M. J., Carlson, L., Gregory, S., & Tynan, B. (2011b). Institutional support for and barriers to the use of 3D immersive virtual worlds in higher education. In *Proceedings of the 28th ASCILITE Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Changing Demands, Changing Directions* (pp. 316–330).

Damer, B. (2008). Meeting in the ether: A brief history of virtual worlds as a medium for user-created events. *Artifact, 2*(2), 94–107.

Davis, A., Murphy, J., Owens, D., Khazanchi, D., & Zigurs, I. (2009). Avatars, people, and virtual worlds: Foundations for research in metaverses. *Journal of the Association for Information Systems, 10*(2), 90–117.

De Freitas, S. (2008). *Serious virtual worlds. A scoping guide. JISC e-Learning Programme*. London: The Joint Information Systems Committee (JISC).

De Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers and Education, 46*(3), 249–264.

De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology, 41*(1), 69–85.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66–69.

Dionisio, J. D. N., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys (CSUR), 45*(3), 34.

Dodgson, M., Gann, D. M., & Phillips, N. (2013). Organizational learning and the technology of foolishness: The case of virtual worlds at IBM. *Organization Science, 24*(5), 1358–1376.

Duncan, I., Miller, A., & Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology, 43*(6), 949–964.

Fonseca, B., Paredes, H., Lt. Rafael, J., Morgado, L., & Martins, P. (2011). A software architecture for collaborative training in virtual worlds: F-16 airplane engine maintenance collaboration and technology. In *Proceedings of the 17th CRIWG Conference on Collaboration and Technology* (pp. 102–109). Berlin, Heidelberg: Springer.

Ghanbarzadeh, R., Ghapanchi, A. H., Blumenstein, M., & Talaei-Khoei, A. (2014). A decade of research on the use of three-dimensional virtual worlds in health care: A systematic literature review. *Journal of Medical Internet Research, 16*(2), e47.

Grady, S. M. (1998). *Virtual reality: Computers mimic the physical world*. New York, NY: Universities Press.

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today, 24*(2), 105–112.

Grimstead, I. J., Walker, D. W., & Avis, N. J. (2005). Collaborative visualization: A review and taxonomy. In *Proceedings of the Ninth IEEE International Symposium on Distributed Simulation and Real-Time Applications* (pp. 61–69).

Hansen, M. 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.

Hasler, B. S., Buecheler, T., & Pfeifer, R. (2009). Collaborative work in 3D virtual environments: A research agenda and operational framework. In A. A. Ozok & P. Zaphiris (Eds.), *Online communities and social computing* (pp. 23–32). Berlin, Heidelberg: Springer.

Hasler, B. S., Tuchman, P., & Friedman, D. (2013). Virtual research assistants: Replacing human interviewers by automated avatars in virtual worlds. *Computers in Human Behavior, 29*(4), 1608–1616.

Haynes, C., & Holmevik, J. R. (1998). *High wired: On the design, use, and theory of educational MOOs*. Ann Arbor: University of Michigan Press.

Hendaoui, A., Limayem, M., & Thompson, C. W. (2008). 3D social virtual worlds: research issues and challenges. *IEEE Internet Computing, 12*(1), 88–92.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55.

Inman, C., Wright, V. H., & Hartman, J. A. (2010). Use of Second Life in K-12 and higher education: A review of research. *Journal of Interactive Online Learning, 9*(1), 44–63.

Jacovi, M., Soroka, V., Gilboa-Freedman, G., Ur, S., Shahar, E., & Marmasse, N. (2006). The chasms of CSCW: A citation graph analysis of the CSCW conference. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work* (pp. 289–298).

Jäkälä, M., & Pekkola, S. (2007). From technology engineering to social engineering: 15 years of research on virtual worlds. *ACM SIGMIS Database, 38*(4), 11–16.

Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers and Education, 53*(1), 169–182.

Johansen, R. (1988). *Groupware: Computer support for business teams*. New York, London: The Free Press.

Jonassen, D. H. (2004). *Handbook of research on educational communications and technology*. New York, NY: Taylor & Francis.

Joslin, C., Di Giacomo, T., & Magnenat-Thalmann, N. (2004). Collaborative virtual environments: From birth to standardization. *IEEE Communications Magazine, 42*(4), 28–33.

Kelton, A. J. (2008). Virtual worlds? "outlook good". *EDUCAUSE Review, 43*(5), 15–22.

Kitchenham, B., Brereton, O. P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering—a systematic literature review. *Information and Software Technology, 51*, 7–15.

Konstantinidis, A., Tsiatsos, T., Demetriadis, S., & Pomportsis, A. (2010). Collaborative learning in OpenSim by utilizing Sloodle. In *Proceedings of the Sixth IEEE Advanced International Conference on Telecommunications* (pp. 90–95).

Krippendorff, K. (1980). *Content analysis: An introduction to its methodology* (The Sage Commtext Series). London: Sage Publications.

Mak, W. K., & Palia, A. P. (2014). Educational perspective of collaborative virtual communication and multi-user virtual environments for business simulations. *Developments in Business Simulation and Experiential Learning, 32*, 200–207.

Messinger, P. R., Stroulia, E., & Lyons, K. (2008). A typology of virtual worlds: Historical overview and future directions. *Journal of Virtual Worlds Research, 1*(1), 1–18.

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers and Education, 56*(3), 769–780.

Montoya, M. M., Massey, A. P., & Lockwood, N. S. (2011). 3D collaborative virtual environments: Exploring the link between collaborative behaviors and team performance. *Decision Sciences, 42*(2), 451–476.

Morgado, L. (2013). Technology challenges of virtual worlds in education and training—research directions. In *Proceedings of the IEEE International Conference on Games and Virtual Worlds for Serious Applications* (pp. 1–5).

Morgado, L., Varajao, J., Coelho, D., Rodrigues, C., Sancin, C., & Castello, V. (2010). The attributes and advantages of virtual worlds for real world training. *The Journal of Virtual Worlds and Education, 1*(1), 15–35.

Moscato, D. R., & Boekman, D. M. (2014). Using 3-D virtual worlds as a platform for an experiential case study in information systems auditing. *Communications of the IIMA, 10*(1), 3.

Okutsu, M., DeLaurentis, D., Brophy, S., & Lambert, J. (2013). Teaching an aerospace engineering design course via virtual worlds: a comparative assessment of learning outcomes. *Computers and Education, 60*(1), 288–298.

Onwuegbuzie, A. J., Leech, N. L., & Collins, K. M. (2012). Qualitative analysis techniques for the review of the literature. *Qualitative Report, 17*, 56.
Otto, O., Roberts, D., & Wolff, R. (2006). A review on effective closely-coupled collaboration using immersive CVE's. In *Proceedings of the ACM International Conference on Virtual Reality Continuum and Its Applications* (pp. 145–154).
Paredes, H., Cassola, F., Morgado, L., Carvalho, F., Ala, S., & Cardoso, F., et al. (2014). Exploring the usage of 3-D virtual worlds and kinect interaction in exergames with elderly. In *Proceedings of the International Conference on Computers Helping People with Special Needs* (pp. 297–300).
Parsons, S., & Cobb, S. (2011). State-of-the-art of virtual reality technologies for children on the autism spectrum. *European Journal of Special Needs Education, 26*(3), 355–366.
Phillips, J., & Berge, Z. L. (2009). Second life for dental education. *Journal of Dental Education, 73*(11), 1260–1264.
Pierzchała, D., Dyk, M., & Szydłowski, A. (2011). Distributed military simulation augmented by computational collective intelligence. In P. Jędrzejowicz, N. T. Nguyen, & K. Hoang (Eds.), *Computational collective intelligence. Technologies and applications* (pp. 399–408). Berlin, Heidelberg: Springer.
Pinkwart, N., & Olivier, H. (2009). Cooperative virtual worlds—a viable eCollaboration pathway or merely a gaming trend? *Electronic Markets, 19*(4), 233–236.
Prasolova-Førland, E. (2008). Analyzing place metaphors in 3D educational collaborative virtual environments. *Computers in Human Behavior, 24*(2), 185–204.
Reeves, B., Malone, T. W., & O'Driscoll, T. (2008). Leadership's online labs. *Harvard Business Review, 86*(5), 58.
Salmon, G. (2009). The future for (second) life and learning. *British Journal of Educational Technology, 40*(3), 526–538.
Savin-Baden, M. (2010). Changelings and shape shifters? Identity play and pedagogical positioning of staff in immersive virtual worlds. *London Review of Education, 8*(1), 25–38.
Savin-Baden, M., Gourlay, L., Tombs, C., Steils, N., Tombs, G., & Mawer, M. (2010). Situating pedagogies, positions and practices in immersive virtual worlds. *Educational Research, 52*(2), 123–133.
Schmeil, A., & Eppler, M. J. (2008). Knowledge sharing and collaborative learning in Second Life: A classification of virtual 3D group interaction scripts. *Journal of Universal Computer Science, 14*(3), 665–677.
Schmeil, A., & Eppler, M. J. (2010). Formalizing and promoting collaboration in 3D virtual environments—a blueprint for the creation of group interaction patterns. In *Proceedings of the International ICST Conference on Facets of Virtual Conference* (pp. 121–134). Berlin, Heidelberg: Springer.
Schneider, D., Moraes, K., Moreira de Souza, J., & Esteves, M. G. P. (2012). CSCWD: Five characters in search of crowds. In *Proceedings of the IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 634–641).
Schroeder, R., Heldal, I., & Tromp, J. (2006). The usability of collaborative virtual environments and methods for the analysis of interaction. *Presence, 15*(6), 655–667.
Sequeira, L. M., Morgado, L., & Pires, E. J. (2014). Simplifying crowd automation in the virtual laboratory of archaeology. *Procedia Technology, 13*, 56–65.
Serino, S., Triberti, S., Villani, D., Cipresso, P., Gaggioli, A., & Riva, G. (2014). Toward a validation of cyber-interventions for stress disorders based on stress inoculation training: a systematic review. *Virtual Reality, 18*(1), 73–87.
Siriaraya, P., Ang, C. S., & Bobrowicz, A. (2014). Exploring the potential of virtual worlds in engaging older people and supporting healthy aging. *Behaviour and Information Technology, 33*(3), 283–294.
Stangl, B., Kastner, M., & Polsterer, F. (2012). Social virtual worlds' success factors: Four studies' insights for the tourism supply and demand side. In *Forty-Fifth IEEE Hawaii International Conference on System Science (HICSS)* (pp. 993–1002).

Stapić, Z., López, E. G., Cabot, A. G., & Ortega, L. M. (2012). Performing systematic literature review in software engineering. In *Proceedings of the Central European Conference on Information and Intelligent Systems* (pp. 441–447).

Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers and Education, 63*, 43–51.

Wallace, P., Presley, A. B., Adrian, A. M., Belden-Adams, K., Caton-Rosser, M., Sleep, D., et al. (2009). Avoidance and attraction in virtual worlds: The impact of affiliative tendency on collaboration. *The International Journal of Technology, Knowledge and Society, 5*(3), 119–126.

Warburton, S. (2009). Second Life in higher education: assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. *British Journal of Educational Technology, 40*(3), 414–426.

Weinberg, E. R., Auerbach, M. A., & Shah, N. B. (2009). The use of simulation for pediatric training and assessment. *Current Opinion in Pediatrics, 21*(3), 282–287.

Wiecha, J., Heyden, R., Sternthal, E., & Merialdi, M. (2010). Learning in a virtual world: Experience with using second life for medical education. *Journal of Medical Internet Research, 12*(1), e1.

Wimpenny, K., Savin-Baden, M., Mawer, M., Steils, N., & Tombs, G. (2012). Unpacking frames of reference to inform the design of virtual world learning in higher education. *Australasian Journal of Educational Technology, 28*(3), 522–545.

Wright, T. E., & Madey, G. (2009). A survey of technologies for building collaborative virtual environments. *The International Journal of Virtual Reality, 8*(1), 53–66.

# Computational Ecosystems in Evolutionary Art, and Their Potential for the Future of Virtual Worlds

**Rui Filipe Antunes, Frederic Fol Leymarie, and William Latham**

## 1 Introduction

The development of computer systems with communities of agents organized as ecosystems is a practice with some already established tradition in the disciplines of Artificial Life (or ALife) (Bisig & Unemi, 2010; Dorin, 2005) and ecology (Railsback & Grimm, 2011). In this chapter, we survey from the last two decades such works developed within the more experimental context of the visual arts. This allows us to characterize the field while identifying structural features and ideas that might provide pointers and contribute to the future of Virtual Worlds.

Computational Ecosystems (CEs) are computer programs that simulate interactions of agents inspired by life in nature (Fig. 1). In a typical CE agents are organized in a hierarchical structure (food chain) and a community dynamics is promoted through the trade of token units of energy and biomass between these agents. In ecology CEs are used when modelling carbon-based contexts and can be considered part of the sub-domain of "agent and individual based models" (Railsback & Grimm, 2011). One of the most well-known example is Daisyworld (Watson & Lovelock, 1983; Lenton & Lovelock, 2001), where the numerical simulation drives the population dynamics of two families of plants (daisies) on an earth-like planet by modelling the number of existing individuals (and their features) over generations. In Daisyworld different rhythms and regulation feedbacks are observed as the environmental conditions change or remain stable (such as dictated by the flow of energy from a virtual sun). By contrast, more recent CEs

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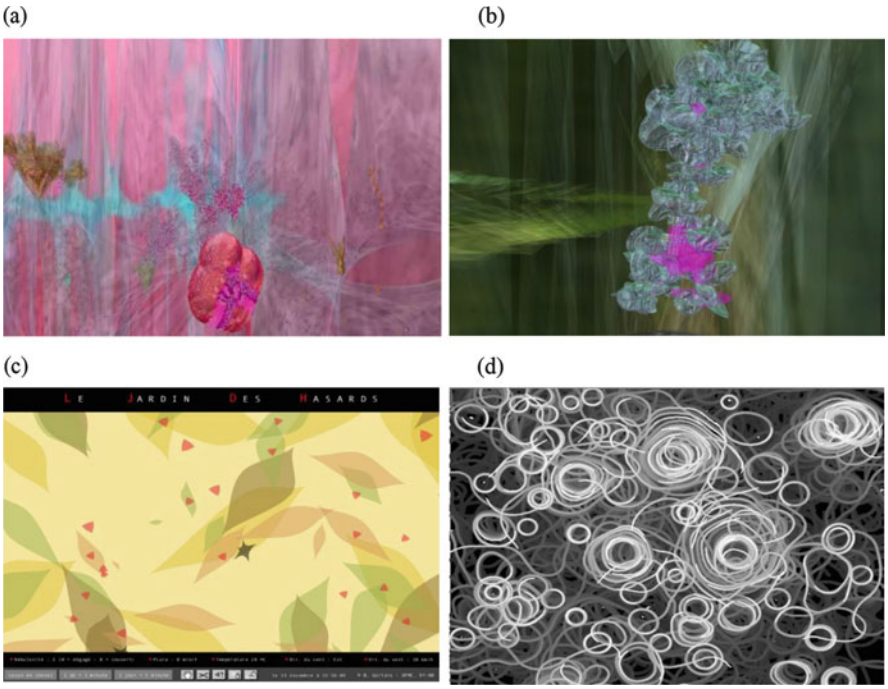


**Fig. 1** (**a**) Still from xTNZ (Antunes & Leymarie, 2008), a CE in which creatures see their physical features (shapes, textures and sounds) evolve over generations by means of Mendelian genetics and Darwinian natural selection (© Antunes & Leymarie, 2008). (**b**) Still from Senhora da Graça (Antunes & Leymarie, 2010): an evolutionary ecosystem exploring the biological phenomenon of epigenetics, where parametric variables of the system affect the physical traits of the creatures (© Antunes & Leymarie, 2010). (**c**) The Garden of Chances (Hutzler, Gortais, & Drogoul, 2000): a visual ecosystem where atmospheric variables inform the growth of the virtual entities (© Hutzler et al., 2000). (**d**) Swarm paintings, where each individual acts as a brush in a canvas (Bornhofen, Gardeux, & Machizaud, 2012) (© Bornhofen, Heudin, Lioret, & Torrel, 2012)

used in the visual arts are characterized by the agency of the modelled individuals, operating in a logic of autonomy and giving rise to phenomena of self-organization and emergence—i.e. the appearance of new unforeseen structures (Bentley & Corne, 2002).

The ALife art practice already has a rich history, in particular since the mid-1990s, with innovative works such as Technosphere (Prophet, 1996), Turbulence (McCormack, 1994) or A-Volve (Sommerer & Mignonneau, 1994). This new art practice has matured through the past two decades and embraced a range of disciplines at the confluence of aesthetic ideas in science and technology, including: kinetic art, generative art, evolutionary art, and aesthetics systems. CEs, as we shall see, play important roles as generative engines in various artistic contexts, including: audio-visual applications (Dorin, 2012), music genesis (Eldridge & Dorin, 2009) or driving the choreography of avatars in virtual worlds (Antunes & Leymarie, 2012).

*Metacreations* (Whitelaw, 2004), *Creative Evolutionary Systems* (Bentley & Corne, 2002), *The Art of Artificial Evolution* (Romero & Machado, 2007) and *Virtual Worlds* (Bornhofen et al., 2012) are some of the key texts in this field. The first is an in-depth critical account of art created with ALife systems, which surveys the theoretical discourses of important works, covering also aspects of the development of CEs. The three other titles provide collections of texts on evolutionary art and virtual worlds, and are mostly technically oriented. In *The Art of Artificial Evolution*, a chapter by Alan Dorin, entitled "A Survey of Virtual Ecosystems in Generative Electronic Art" provides an overview of art making use of CEs (Romero & Machado, 2007, Ch. 14). Our research complements these previous works by mapping out this field, and in particular, it extends Dorin's older survey, by virtue of providing a detailed systematization and objective classification of this area of knowledge. We study this area and the various contexts in which works are presented, as well as consider their formal attributes and the user experience qualities. Doing so, we outline patterns and common features which might help to refine and better characterise the field and grasp the uniqueness and creative potential of this practice. In the following section we first look at Evolutionary Art (EvoArt) (Boden & Edmonds, 2009), an aesthetic domain which includes CEs used in ALife art, and start identifying some of the fundamental features common to these systems.

## *1.1 The Three Main Genres of Evolutionary Art*

Evolutionary Art is a form of artistic expression characterized by the instrumentalization of processes of evolution by combining the principle of natural selection (after Darwin and Wallace) with the rules of genetics (after Mendel) in order to promote the creation of artefacts obeying a new aesthetic.

### 1.1.1 The First Genre: Gtype–Ptype

EvoArt encodes a blueprint (the genotype—Gtype) which is then converted to its iconic or audible (or multi-media) representation (the phenotype—Ptype). This approach is borrowed from the framework of Genetic Algorithms (GAs) in Computer Science, where syntactic elements are translated into their semantic interpretation. A community evolves through gene-lead processes. The 'best' in a pool of individuals are chosen to procreate or further evolve. In the process they will blend their successful Gtypes in a new pool of individuals which will replace the old ones. With GAs the fitness criteria determining which individuals are to be kept are problem-dependent.

With traditional EvoArt it is a human operator who controls the selective pressure known as the Interactive GA (or IGA). The complexity of this process of conversion from Gtype to Ptype is open to artistic creativity and the linearity and distance involved in this process of transformation differ widely amongst artists.

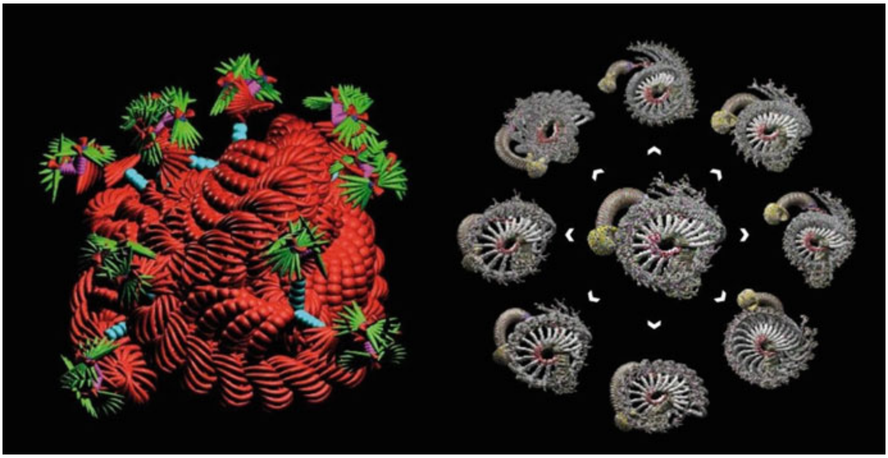

**Fig. 2** William Latham uses a grammar of morphological operators and transformations to encode the information contained in the "genomes" of his artefacts (Latham, 1989; Todd & Latham, 1992). An interactive process of selecting successive genomes generate a series of images (here in 3D) based on a process of recombination and mutation of the genes. At each generative step, the artist selects the preferred of these new images to serve as progeny for the next iteration. On the *left* is shown one outcome of an EvoArt session: PlantForm (© Latham 1989), and on the *right* is illustrated one evolutionary step in another session where the central parent, once selected by the artist, is used to create eight new descendants (© Latham 1991)

**Fig. 3** Extinct Image, Karl Sims, 1990. From "Artificial Evolution for Computer Graphics," ACM SIGGRAPH'91 Conference Proceedings, Las Vegas, Nevada, July 1991

The diversity of the outcomes this methodology entails is illustrated for example by computational evolutionary art pioneers Latham and Sims: William Latham produces 3D morphologies based on a process of shape deformation (Fig. 2), while Karl Sims generates abstract imagery (Fig. 3) based on a language of mathematical and visual operators (Lambert, Latham, & Leymarie, 2013; Whitelaw, 2004).

### 1.1.2 The Second Genre: Virtual Communities

The Gtype–Ptype metaphor has also been explored by applying it to whole populations of interacting autonomous agents defined by CEs. In addition to the Gtype–Ptype translation process, the autonomy of the individuals generates an interesting dynamics of self-organization and emergence with cyclic changes of density. Each of the agents in the community emulates a simplified form of the life cycle of generic carbon-based life forms. In a regular CE, genetic characteristics such as the size or speed of the agents is carried over from parents to children when individuals replicate, in a process that emulates sexual reproduction. The selective pressure is expressed in how well the individuals perform in the system, in order to perpetuate their genetic heritage. Energy might be required for the activities of these individuals, such as moving, running, or simply breathing. The population competes for energy and space, and this dynamic of energy transfer occurs in predatory acts. When the energy level of an individual becomes too low, it is considered dying and removed from the community.

Systems can be distinguished by the way they are organized based on patterns of energetic exchange. A reading of the literature provides us with four dominant models: homogeneous, chemostat, heterogeneous and food-web. We describe these next.

1. *Homogeneous model:*

   The simplest model is the one using homogeneous populations (Fig. 4-Hm). Interactions are established within a closed community (i.e. without exterior exchanges) of similar individuals. This is the model used, for instance, in A-Volve (Sommerer & Mignonneau, 1994). In order to survive in the virtual tank of A-Volve, fishes need to capture other fishes co-inhabiting in the tank. In this type of community the interactions are mainly pre-established during the design stage of production. However, they may also be designed in order to evolve with time, generating dynamic food webs which shrink or expand with the emergent (unforeseen) complexity of the interactions.
2. *Chemostat model:*

   In classical chemostats (or static chemical environments) external input feeds a constant regulated flow of resources to a population of cells or chemical agents (Fig. 4-C). Populations of this type (C) can be characterized as having a sub-population of consumers distinguished from its source of energy. This might be a set of 'food-bits' or a sub-population of producers. These two non-interbreeding groups are usually represented using distinct data-structures. In Genepool (Ventrella, 2005), for instance, dynamic individuals feed on passive 'food-bits'. In general, the sub-population of consumers is used to model heterotrophic individuals, such as carnivores, that mostly rely on other organisms to survive. The source of energy is used to simulate autotrophs, such as green plants, which can manufacture food from their abiotic environment. Tierra (Ray, 1995), and Polyworld (Yaeger, 1994) are classic works which employ this type of design. In GenePool and Polyworld the source of energy is constituted by

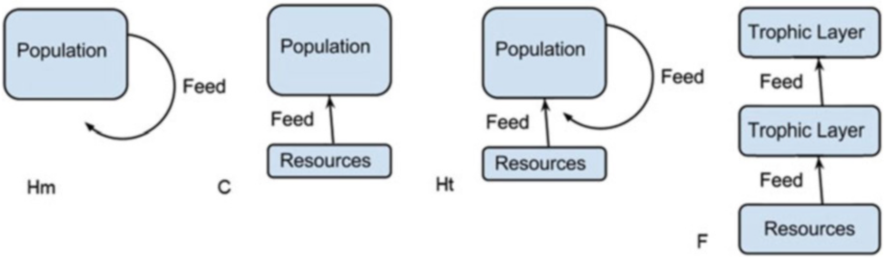


**Fig. 4** (Adapted from Antunes' thesis (Antunes, 2014).) Four distinct models of population, from *left to right*. *Hm* Homogeneous, *C* Chemostat, *Ht* Heterogeneous, and *F* Food web

passive abiotic units which appear, as if by magic, on the surface of the simulated world. Tierra is a special case where individuals compete for units of processing time. Extended derivations from this model creatively play with the flow of energetic input. In Life Spacies II (Sommerer & Mignonneau, 2000), or Black Shoals (Demos, 2012; Portway, Autogena, Hoile, & Riley, 2004), the appearance and growth of producers is not constant and infinite as in the previous examples, but rather is dependent on some actions external to the community. Such external inputs are performed either by the public in the installation space, as in the case of Eden (McCormack, 2001) and Life Spacies II (Sommerer & Mignonneau, 2000), or by some other external factors such as movements of shares on the Stock Exchange, as in Black Shoals (Demos, 2012; Portway et al., 2004), or even variations in the weather as in Garden of Chances (Hutzler et al., 2000).

3. *Heterogeneous model:*

   This model is a combination of the previous two. It describes works where individuals in the population feed not only from an external source but also from other members of their community (Fig. 4-Ht). This is the type of interaction at play in xTNZ (Antunes & Leymarie, 2008) and Senhora da Graça (Antunes & Leymarie, 2010). In these CEs, individuals have dietary constraints emulating some form of chemical metabolism, which restricts the range of possible preys. These metabolic constraints force the emergence of multilayer food webs (Saruwatari, Toqunaga, & Hoshino, 1994) where some individuals are able to exclusively prey on producers, some other individuals are only able to prey on other consumers, while others are able to prey on both producers and consumers.

4. *Food-web model:*

   In contrast to the emergent food webs previously described, in Technosphere (Prophet, 1996) or Eidea (Mitchell & Lovell, 1995), individual metabolisms and trophic interactions are pre-established (Fig. 4-F). In these projects the ecosystem is typically composed of three different trophic levels that emulate carnivores, herbivores and plants. Here evolutionary forces do not change individual diets as happens with some of the previous models (such as Hm and Ht). Some commercial games, drawing on evolution, make use of this model of

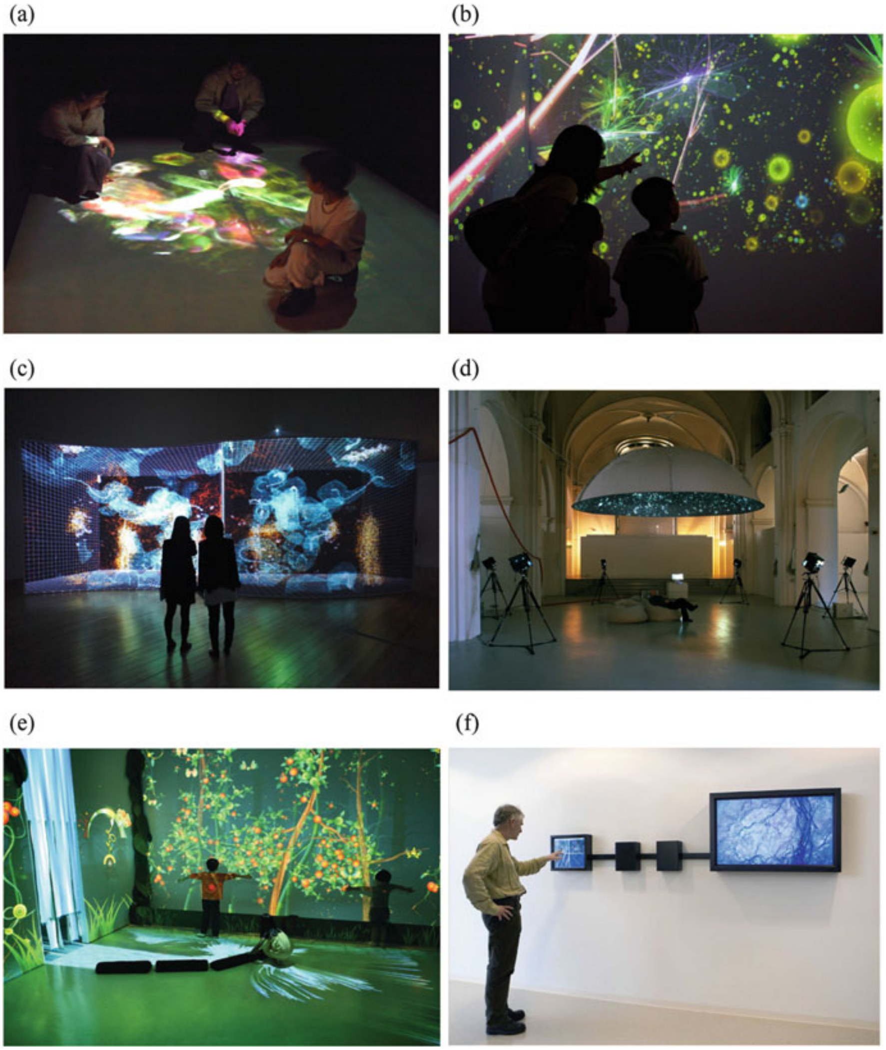


**Fig. 5** Various CEs in public exhibition in gallery context: (**a**) C.-Y. Chen and J.-C. Hoyami: *Quorum Sensing* (Chen & Hoyami, 2007), Art Outsiders Festival, Paris, 2002; (**b**) Haru Ji and Graham Wakefield: *FluidSpace*, 2009 Ji (2012); (**c**) Haru Ji and Graham Wakefield: *Time of Doubles* (Ji, 2012; Wakefield, 2012), 2012; (**d**) Lise Autogena, Joshua Portway and Cefn Hoiles: *Black Schools* (Demos, 2012) at Tate Britain in London, 2002; (**e**) Emily Gobeille and Theo Watson: *Funky Forest* (Watson & Gobeille, 2007), in 2008; (**f**) Driessens and Verstappen: *E-volver* (Driessens and Verstappen, 2006), LUMC Leiden, photo Gert Jan van Rooij 2006

community. The procedural creatures of Spore, for instance, have predefined 'metabolic' capabilities and scope (Arts, 2009). The user can only choose where his/her creature will fit in the a-priori rigid hierarchy of the food-chain.

CEs used in EvoArt are structured upon one of the patterns described above in order to explore processes of self-organization and emergence. As the individuals compete for energy trying to survive and perpetuate their genetic heritage the community becomes increasingly heterogeneous. These processes of self-organization are the main mechanisms used to generate heterogeneity and novelty in the artistic works (Figs. 1 and 5). We have also identified a growing tendency to have Gtypes directly sonified or visualized. Wakefield and Ji, for instance, produce sounds directly from the transcription of the Gtype data (Wakefield & Ji, 2009).

#### 1.1.3 The Third Genre: CEs Dynamics–Ephemeral Events, Internal States

We propose a third genre characterized by artists who are interested in the ephemeral states of the system and the dynamics generated by its individuals, where the system's internal states translate into actions performed by agents. In the work *Unfinished Symphonies—songs from a 3½ worlds* we can read: "the rhythm list increases when the creature eats a tree and decreases as it ages or fails to find food". Then, referring to another work: "Each creature starts its life as a soprano [. . .] having only one body segment and a high pitched voice. When it reaches puberty, it becomes an Alto with one extra body segment and a slightly lower voice. Altos are also able to bear children. Later in life, the alto transforms into a Tenor and then later still becomes a Bass" (Berry, Rungsarityotin, & Dorin, 2001). Another example is provided by the soundscapes produced by Eldridge and Dorin. These are granular compositions where timbre and pitch depart from the spatial aggregation of the individuals in the virtual environment (Eldridge & Dorin, 2009). Antunes and Fol Leymarie take advantage of the internal dynamics and the ephemeral states generated by CEs to generate choreographies and animate dancers (Antunes & Leymarie, 2012) and groups of conversational humanoids (Antunes & Leymarie, 2013).

Before we present and discuss our survey's results, we describe next the methodological aspects.

## 2 Methodology

### *2.1 Domain of the Survey*

To initiate our study we went through the proceedings of the main scientific conferences covering the relevant genres of work, including: EvoMusArt, Generative art, Genetic Evolutionary Computation Conference, the IEEE Congress on Evolutionary Computation, and Artificial Life. We also looked at a collection of established books with surveys on ALife art or EvoArt, including:

Creative Evolutionary Systems (Bentley & Corne, 2002), Metacreations (Whitelaw, 2004), The Art of Artificial Evolution (Romero & Machado, 2007), and Virtual Worlds (Bornhofen et al., 2012). Finally we looked at art magazines such as Art Forum and journals such as the International Journal of Arts and Technology and the Journal of Virtual Worlds Research. From these we have selected a sample of 40 papers. Our aim was not of producing an exhaustive scrutiny of the field, but rather to have a sufficient sample of important works, from which we could derive with good confidence interesting conclusions. On the one hand, this sample should cover the full spectrum of activities with regards to artistic styles and uses of the CE framework, and on the other hand, it should be sufficiently well distributed throughout the 20 years of our set time frame (1993–2013). We followed two main selection criteria: the art-criterion and the CE-criterion. The first constrained the selection to works that have been presented or discussed as artistic projects, ideally exhibited in a gallery, museum or an art festival or shown/distributed on the internet. The second criterion constrained the selection to instances where the artificial beings that populate the world emulate aspects of biological life forms. This includes works where individuals are: represented by Gtype-seeds, or exchange energy or mass, or emulate metabolic cycles (these might include birth, growing morphologies, reproduction and death). Ideally, works should include all these factors, but due to the variety of approaches, this criterion was loosened to the presence of at least one criterion.

#### 2.1.1 Surveyed Works

The list of selected works (in reverse chronological order) is presented in Table 1.

### *2.2 Variables and Taxonomy*

To describe the selected works we modified a taxonomy from Carvalhais (2010) who recommends to classify works of generative art via an adaptation of Aarseth's taxonomy for cybertexts (Aarseth, 1997). Our taxonomy includes detailed aspects of the physical implementation of the works in a public exhibition space, while some redundant aspects to the nature of CEs (such as the existence or not of dynamism in the works) are removed. We have divided into three groups the variables used for classification to: (i) describe contextual properties; (ii) capture the user experience; and (iii) describe formal properties. We describe these three groups and there constitutive variables below.

**Table 1** List of 40 surveyed works

| | Work | Author | Year |
|---|---|---|---|
| 1 | Codeform (McCormack, 2012) | Jon McCormack | 2012 |
| 2 | Swarm-art (Al-Rifaie & Bishop, 2013) | Mohammad Majid et al. | 2012–2013 |
| 3 | Untitled (Bornhofen et al., 2012) | Stefan Bornhofen et al. | 2012 |
| 4 | Where is Lourenço Marques? (Antunes, 2012; Antunes & Leymarie, 2013) | Antunes and Leymarie | 2012–2013 |
| 5 | Time of doubles (Ji, 2012; Wakefield, 2012) | Ji and Wakefield | 2012 |
| 6 | Pandemic (Dorin, 2012) | Alan Dorin | 2012 |
| 7 | Vishnu's Dance of Life and Death (Antunes & Leymarie, 2012) | Antunes and Fol Leymarie | 2011 |
| 8 | EvoEco (Kowaliw, McCormack, & Dorin, 2011) | Kowalik et al. | 2011 |
| 9 | Cycles (Bisig & Unemi, 2010) | Bisig and Unemi | 2010 |
| 10 | Senhora da Graça (Antunes & Leymarie, 2010) | Antunes and Fol Leymarie | 2010 |
| 11 | Sonic Ecosystem (Bown & McCormack, 2010) | Bown and McCormack | 2009 |
| 12 | Constellation (Dorin, 2009a) | Alan Dorin | 2009 |
| 13 | Habitat (Dorin, 2009b) | Dorin | 2009 |
| 14 | Untitled experiment (Niches) (McCormack & Bown, 2009) | McCormack and Bown | 2009 |
| 15 | Fluid space (Ji, 2012; Ji & Wakefield, 2012) | Ji and Wakefield | 2009 |
| 16 | Quorum Sensing (Chen & Hoyami, 2007) | Chen and Hoyami | 2008 |
| 17 | Filterscape (Eldridge & Dorin, 2009) | Eldridge et al. | 2008 |
| 18 | Infinite game Ji (2012); Ji and Wakefield (2012) | Ji and Wakefield | 2008 |
| 19 | Colour cycling (Eldridge, Dorin, & McCormack, 2008) | Eldridge et al. | 2008 |
| 20 | xTNZ (Antunes & Leymarie, 2008) | Antunes and Fol Leymarie | 2006 |
| 21 | Funky forest (Watson & Gobeille, 2007) | Watson and Gobeille | 2007 |
| 22 | E-volver (Driessens and Verstappen, 2006) | Driessens and Verstappen | 2006 |
| 23 | Plague (Dorin, 2006) | Alan Dorin | 2006 |
| 24 | Ambient Light (Spinster, 2007) | Annie Spinster | 2006 |
| 25 | Lifedrop (Heudin, 2012) | Jean-Claude Heudin | 2004 |
| 26 | Meniscus (Dorin, 2003) | Alan Dorin | 2003 |
| 27 | Black Sholes (Demos, 2012; Portway et al., 2004) | Autogena, Portway and Hoiles | 2001 |
| 28 | Eden (McCormack, 2001) | Jon McCormack | 2001 |
| 29 | Biotica (Brown, Aleksander, MacKenzie, & Faith, 2001) | Richard Brown | 2001 |
| 30 | Living melodies (Dahlstedt & Nordahl, 2001) | Dahlstedt and Nordahl | 2001 |
| 31 | Listening skies (Berry et al., 2001) | Berry et al. | 2001 |
| 32 | Iki Iki (Sommerer, Mignonneau, Lopez-Gulliver, & Satomi, 2001) | Sommerer et al. | 2001 |

(continued)

**Table 1** (continued)

| | Work | Author | Year |
|---|---|---|---|
| 33 | Life Spacies (Sommerer & Mignonneau, 2000) | Sommerer and Mignonneau | 2000 |
| 34 | Garden of Chances (Hutzler et al., 2000) | Hutzler at al. | 2000 |
| 35 | Relazioni Emergenti (Annunziato & Pierucci, 2000) | Annunziato and Pierucci | 2000 |
| 36 | Nagual experiment (Annunziato, 1998) | Mauro Annunziato | 1998 |
| 37 | NerveGarden (Damer, Marcelo, Revi, Furmanski, & Laurel, 2005) | Damer et al. | 1998 |
| 38 | Technosphere (Prophet, 1996) | Jane Prophet and Gordon Selley | 1996 |
| 39 | EIDEA (Mitchell & Lovell, 1995) | Mitchell and Lovell | 1995 |
| 40 | A-volve (Sommerer & Mignonneau, 1994) | Sommerer and Mignonneau | 1994 |

### 2.2.1 Contextual Variables

*Context* This refers to the main context of the work, to its function. Does the artwork tell or *narrate*, *inform* or *document*, does it *visualize*, *sonify*, *monitor*, *mediate*, *transform*, *collect* or *store* an event, process or story?

*Referentiality* Many works in EvoArt are self-referential or reflect upon *life*; however, a significant number also reflect about *societal*, *political*, *economic* or *environmental* processes.

*Autonomy* This variable describes the focus of the work in terms of input. Is the work independent from external influences (autonomous) or does it need external sources of input like the meteorological information required by EIDEA (Mitchell & Lovell, 1995) (data-driven), or user-input designing and adding new creatures. Accepted values are: *autonomous*, *data-driven*, or *user*.

### 2.2.2 User Experience (Interactivity)

We consider now variables describing levels and types of interactivity of a CE.

*Perspective* This binary parameter identifies the level of commitment of the audience with respect to the emergence of the work's outcome or storyline. When the audience plays a direct role in the narrative the work is considered *personal*, and *impersonal* otherwise.

*User Functions* Members of the audience may observe, explore, activate, control, select, navigate, participate, or leave traces. These interactions are classified as one of three possibilities: *interpretative* (observe), *explorative* (explore, navigate, select) or *configurative* (activate, control, leave trace, participate).

*Linking* This variable denotes the existence of devices and processes that make a CE reactive to interactions with the audience. Accepted values are: *none*, *explicit*, or *implicit*. Explicit stands for works where there is a direct involvement of the user, usually via a haptic device such as a mouse, touch screen, tablet or pod. Implicit is when the body or its physical presence in space is captured with the help of non-interfering devices such as infra-red cameras.

*Modes* Modalities of perception engaging the user are captured by this variable, including the: *visual*, *haptic*, *aural*, *movement* and *procedural* modes. Movement may include subtle dynamic events such as finger gestures or eye gaze. Procedural refers to the cognitive dimension of the experience, where in contrast to the other modes, a rational understanding of the processes involved in the construction of the work is implied. For example, Technosphere (Prophet, 1996) builds on the illusion of an "out-there" abstracting the processes involved in its construction, whereas in works such as Cycles (Bisig & Unemi, 2010) this procedural dimension beyond what is seen is emphasized by means of a more abstract form of representation using lines and simple geometric forms in an aesthetic popularized by computer screensavers which enhances (makes explicit) the presence of the medium and its processes. Modalities of smell and taste could potentially be included here, but this is unnecessary in our study as, to the best of our knowledge, no recent work explores such territories.

*Determinability* This binary indicator specifies if different interactions from the audience with the same artefact may result in similar experiences or not. This variable is subordinate to the user-function, as unique experiences exist in the explorative and dynamic modes. Accepted values are *yes* or *no*. Given the subjectivity involved in accessing what are "similar" experiences, we opted to just classify as determinable those works presented in still format, as "drawings" as McCormack puts it (McCormack & Bown, 2009).

*Access* We assume the whole of the artefact is available at all times (e.g. during an exhibit period), but its access can be *controlled* or *random*. A controlled situation is illustrated for example by Listening Skies (Berry et al., 2001) where the user creates a "listener" from which point of view the world will be perceived, or by Meniscus (Dorin, 2003) where the user changes the water level, thus conditioning and controlling the outcomes. A random situation is illustrated by xTNZ (Antunes & Leymarie, 2008) where the whole of the virtual environment can be explored in an unconstrained fashion.

*Class* This variable is used to indicate the computational class of the work: (1) producing *static non-transient* outputs; (2) producing *static transient* outputs; (3) exhibiting *complex* behaviours. An example of a static non-transient output is a static image. A static transient output defines works that keep changing over time but not in a structural way. Works with complex behaviours are locally structured, partially predictable, and will exhibit random behaviour changes in surprising and unexpected ways.

### 2.2.3 Formal Variables

The final set of variables is used to describe the formal properties of the artefacts and how they are presented in public.

*Format* This describes the physical manifestation of the artefact including what format was chosen to present a CE to the public. The "format" can take one of six meanings: (i) *installation* denotes works designed to transform the perception of space by surrounding (embedding) the user; (ii) *sculpture* denotes objects that are observed as a self-contained arrangements of forms; (iii) *video* and (iv) *interactive-video* stand for works where the artefact is presented in a minimalistic technical form with the help of a projector—note however that given the nature of CEs the term video refers here to content that is produced in real-time; (v) *software-application* works are experienced in the intimacy of the computer; (vi) *still-imagery* stands for printed works of digital photography.

*Composition* The second formal variable describes the mode of representation used in the composition, depending if *visuals* and/or *sounds* explicitly stand for some external entity and if the work is a *collection* of representational elements or is *abstract*.

*Visual Form* This descriptor is used to indicate how individuals are represented visually in the ecosystem. To cover the wide range of approaches, this category accepts a graded scale of values. Individuals can be represented by *dots*, *lines*, *surfaces*, *volumes* or *ephemeral*/translucent forms.

*Depth* This binary parameter is complementary to the visual form and indicates the presence of foreshortening in the representation. Two values are accepted to denote bi-dimensional (*2D* or flat) or three-dimensional (*3D* or volumetric) representations.

*Colour* Works may be *monochromatic* or *multi-coloured*. Monochromatic works are few, and include black and white as well as grey-level pieces.

*SFX* Special effects (SFX) indicates the level of graphical sophistication, such as surface details, texture mixing, or the use of smooth elementary units and solid objects versus complex ones. Accepted values are *yes* or *no* (i.e. complex or simple).

*Sonification* There are multiple alternatives for the use of sound. The main dichotomy is between *pre-recorded* and *synthesized* (in real-time) sounds. A sonification effect can be composed of preselected elements, which might be played for instance as screams by individuals. Alternatively, sounds produced may be granular, i.e. synthesized and played simultaneously by different units of a CE, which is typical of swarming and particle-based approaches.

*Display* The CE is ultimately a system running on a computer. This (almost always) requires a visualisation. The technology used to present the CE to the public is captured by this descriptor: *frontal-*, *vertical-*, *retro-*, or *multiple-projection*, *computer-screen*, *touch-screen* or *mixed-reality*.

*Scale* This variable describes the size relationship of the individuals from the virtual population with respect to the human body. Accepted values are: *micro* for small sizes (typically less than 0.1 m), *human* for sizes similar to the human body and parts (up to 3 m); and *macro* for other larger sizes (e.g. at architectural/ urban scales).

### 2.2.4 Summary

We have presented a set of variables based on the taxonomy introduced by Carvalhais to classify generative artworks (Carvalhais, 2010). Some of the original categories were removed—i.e. Dynamics and Transiency—since they are redundant in the context of CEs. Some others had their name changed to better clarify their relation to CEs: Individual was changed to Visual Form, Sound to Sonification, Blending to SFX, shape to surfaces, transparencies to ephemeral. The nineteen selected variables are as follows:

1–Context (narrate, inform, visualize, sonify, monitor, mediate, transform, collect, store); 2–Referentiality (life, societal, political, economic, environmental); 3–Autonomy (autonomous, data-driven, user); 4–Perspective (personal, impersonal); 5–User Functions (interpretative, explorative, configurative); 6–Linking (none, explicit, conditional); 7–Modes (visual, haptic, aural, movement, procedural); 8–Determinability (yes or no); 9–Access (random, controlled); 10–Class (1 (static non-transient), 2 (static transient), 3 (complex)); 11–Format (installation, sculpture, video, interactive-video, sw-app (software-application), still (imagery)); 12–Composition (representational, abstract); 13–Visual Form (dots, lines, surfaces, volumes, ephemeral); 14–Depth (2D, 3D); 15–Colour (mono (chrome), multi (coloured)); 16–SFX (yes (complex), no (simple)); 17–Sonification (pre-selected, granular); 18–Display (frontal (projection), retro (projection), multi(projection), (computer-) screen, or touch); 19- Scale (micro, human, macro).

## 3 Results and Characterization

The following tables show the classification for the three main variable types: Contextual, Interactivity, Formal. These tables were produced from a close inspection of: project websites, papers describing the implementations, and other material when available (e.g. blogs, reviews). A rapid look at the tables shows a great heterogeneity of agendas and outcomes. We discuss below the content of each table in turn. Note that WisLM (Antunes, 2012; Antunes & Leymarie, 2013) and Technosphere (Prophet, 1996) appear twice in each table as they have been exhibited both (a) in galleries and (b) on the internet; also, Fluid space is a later and enhanced version of Infinite Game (Ji, 2012), and similarly with Pandemic (Dorin, 2012) in relation to Plague (Dorin, 2006); note also that tables are organised by date of publication, from most to least recent.

### 3.1 Contextual Variables

First, we consider the contextual aspects of the 40 projects surveyed as listed in Table 2.

Summations of variable values are illustrated in Fig. 6.

The first aspect that emerges from the diagrammatic summary (Fig. 6) is that CEs operate autonomously within an aesthetic that is largely focused around visualizations of processes of life. A close inspection of Table 2 reveals that the internal dynamics of the processes of life, such as the spread of diseases in Pandemic (Dorin, 2012) or niche-formation in Relazioni Emergenti (Annunziato & Pierucci, 2000), and self-referentiality, such as the abstract compositions resulting from processes of natural selection in Galatema (Lioret, 2012), dominate largely representing nearly 70 % of the referentiality spectrum. Together, environmental, societal, political and the economy are themes which represent only about a third of the spectrum. This should not be too surprising if we take into consideration the historical agenda of ALife which has often been used in science to demonstrate biological phenomena and offer suggestions on how such phenomena may arise and function. CEs in particular have been used to draw conclusions about complex adaptive systems. As Whitelaw underlines: ALife art is engaged in the pursuit of an agenda where visualizing and emphasizing life and its processes is a top priority (Whitelaw, 2004). This situation indicates potential avenues to explore in the future by artists wanting to demarcate themselves from the main themes of previous works.

Looking into the specifics of projects from the point of view of the Context variable, it is not too surprising to find that most works operate in the visual realm (95 %), and almost half of them make use of the aural dimension (45 %). More recent works tend to explore the two modalities integrated together. The other main common denominator is the exploration of interactions with the audience.

Only a small minority or works require external data as input (7 %), but, by contrast, the majority requires the audience to be active and perform actions directly impacting the CE (60 %). Some works are entirely dependent on such actions: for instance, Cycles (Bisig & Unemi, 2010) requires the user to put their hand under the device containing the camera in order to let the virtual agents feed themselves. In other works however the user only interferes with the natural evolution of the CE, such as in A-Volve (Sommerer & Mignonneau, 1994), where the audience may insert a new fish in the pool, thus changing the *status quo* of the virtual tank. The following section analyses the interactive aspect in more detail.

**Table 2** Contextual classification of the 40 surveyed works

| Work | Context | Referentiality | Autonomy |
|---|---|---|---|
| Codeform (McCormack, 2012) | Vis + sonify | Societal | User |
| Swarm-art (Al-Rifaie & Bishop, 2013) | Vis + sonify | Life | User |
| Untitled (Bornhofen et al., 2012) | Visualize | Life | Autonomous |
| WisLM (a) (Antunes, 2012; Antunes & Leymarie, 2013) | Vis + mediate | Political | Autonomous |
| WisLM (b) (Antunes, 2012; Antunes & Leymarie, 2013) | Vis + mediate | Political | Autonomous |
| Time of doubles (Ji, 2012; Wakefield, 2012) | Vis + sonify | Life | User |
| Pandemic (Dorin, 2012) | Vis + sonify | Life | User |
| Vishnu's (Antunes & Leymarie, 2012) | Visualize | Societal | Autonomous |
| EvoEco (Kowaliw et al., 2011) | Visualize | Life | User |
| Cycles (Bisig & Unemi, 2010) | Visualize | Life | User |
| SraGraca (Antunes & Leymarie, 2010) | Visualize | Environmental | Autonomous |
| Constellation (Dorin, 2009a) | Visualize | Life | Autonomous |
| Habitat (Dorin, 2009a) | Vis + sonify | Life | Autonomous |
| Niches (McCormack & Bown, 2009) | Visualize | Life | Autonomous |
| Sonic Ecosystem (Bown & McCormack, 2010) | Vis + sonify | Life | Autonomous |
| Fluid space (Ji, 2012) | Vis + sonify | Life | User |
| Quorum Sensing (Chen & Hoyami, 2007) | Vis + sonify | Life | User |
| Filterscape (Eldridge & Dorin, 2009) | Sonify | Life | Autonomous |
| Infinite game (Ji, 2012) | Vis + sonify | Life | User |
| Colour cycling (Eldridge et al., 2008) | Visualize | Life | Autonomous |
| Funky forest (Watson & Gobeille, 2007) | Vis + sonify | Environmental | User |
| xTNZ (Antunes & Leymarie, 2008) | Vis + sonify | Societal | User |
| E-volver (Driessens and Verstappen, 2006) | Visualize | Life | User |
| Plague (Dorin, 2006) | Vis + sonify | Life | User |
| Ambient light (Spinster, 2007) | Visualize | Life | User |
| Lifedrop (Heudin, 2012) | Visualize | Life | Autonomous |
| Meniscus (Dorin, 2003) | Vis + sonify | Life | User |
| Black sholes (Demos, 2012; Portway et al., 2004) | Visualize | Economic | Data-driven |
| Eden (McCormack, 2001) | Vis + sonify | Life | User |
| Biotica (Brown et al., 2001) | Vis + sonify | Life | User |
| Living Melodies (Dahlstedt & Nordahl, 2001) | Sonify | Life | Autonomous |
| Listening skies (Berry et al., 2001) | Vis + sonify | Life | User |
| Iki Iki (Sommerer et al., 2001) | Visualize | Life | User |
| Life spacies (Sommerer & Mignonneau, 2000) | Visualize | Societal | User |
| Garden of Chances (Hutzler et al., 2000) | Vis + son + monitor | Environmental | Data-driven |
| NerveGarden (Damer et al., 2005) | Visualize | Life | User |

(continued)

**Table 2** (continued)

| Work | Context | Referentiality | Autonomy |
|---|---|---|---|
| Nagual experiment (Annunziato, 1998) | Visualize | Life | Autonomous |
| Relazioni Emergenti (Annunziato & Pierucci, 2000) | Vis + sonify | Life | User |
| Technosphere (a) (Prophet, 1996) | Visualize | Societal | User |
| Technosphere (b) Prophet (1996) | Visualize | Societal | User |
| EIDEA (Mitchell & Lovell, 1995) | Vis + son + monitor | Environmental | Data-driven |
| A-volve (Sommerer & Mignonneau, 1994) | Visualize | Life | User |

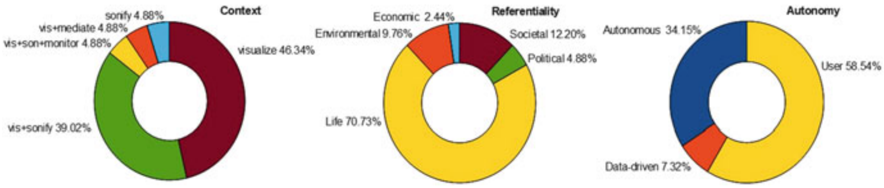


**Fig. 6** Diagrammatic summary of the context of the works

## 3.2 *Interactivity*

Table 3 and Fig. 7 capture and summarise the interactivity of the 40 works.

With no exception all the works under scrutiny produce either a visual or audio outcome to be experienced and appreciated. This naturally results from the selection criteria used, which required works to be artistic or exhibited in public. The audience is an integral part of most works and the interactive devices are explicit and visible for the large part (45 %). In 22 % of the instances however, the body presence is captured without the help of any accessory haptic devices, usually by means of computer vision techniques. This percentage would have substantially risen if we had considered only interactive works. Also, note that in the near future, the new possibilities provided by interactive technologies such as Microsoft's Kinect and its descendants are likely to have a major impact on the field (i.e. raise the influence of body movement and gesture-based interactions).

The explorative component is present in 38 % of the works, but only a rather small number of projects (25 %) let the user configure the settings (or interfere with the evolution). Meniscus (Dorin, 2003) provides an example where the audience controls the level of virtual water in the simulation. This small percentage of works allowing configurative tasks is rather surprising, in particular since we have considered the actions of adding or removing members of the population (of the CE) as part of this category. As mentioned earlier one conclusion to derive from our study is the untapped potential for greater levels of interactivity, in particular for the exploration of the configurative roles played by the audience.

We further underline that although a CE is in essence a complex system often exhibiting non-determinable outcomes, it remains constrained by parameters

**Table 3** The user (interactivity) functions of the 40 surveyed works

| Work | Perspect. | User | Link | Mode | Det. | Acces. | Class |
|---|---|---|---|---|---|---|---|
| Codeform (McCormack, 2012) | Personal | Configurative | Implicit | 3 | No | Random | 2 |
| Swarm-art (Al-Rifaie & Bishop, 2013) | Personal | Configurative | Explicit | 2 | No | Random | 2 |
| Untitled (Bornhofen et al., 2012) | Impersonal | Interpretative | None | 1 | Yes | Controlled | 1 |
| WisLM (a) (Antunes & Leymarie, 2013) | Impersonal | Explorative | Explicit | 3 | No | Random | 2 |
| WisLM (b) (Antunes & Leymarie, 2013) | Impersonal | Explorative | Explicit | 3 | No | Random | 2 |
| Time of Doubles (Ji, 2012; Wake-field, 2012) | Personal | Explorative | Implicit | 5 | No | Random | 3 |
| Pandemic (Dorin, 2012) | Personal | Interpretative | Implicit | 4 | No | Random | 2 |
| Vishnu's (Antunes & Leymarie, 2012) | Impersonal | Interpretative | None | 2 | No | Random | 2 |
| EvoEco (Kowaliw et al., 2011) | Personal | Explorative | Explicit | 3 | No | Controlled | 1 |
| Cycles (Bisig & Unemi, 2010) | Personal | Interpretative | Explicit | 3 | No | Random | 3 |
| Sra Graca (Antunes & Leymarie, 2010) | Impersonal | Interpretative | Explicit | 4 | No | Random | 2 |
| Constellation (Dorin, 2009a) | Impersonal | Interpretative | None | 3 | No | Random | 2 |
| Habitat (Dorin, 2009a) | Impersonal | Interpretative | None | 3 | No | Random | 2 |
| Niches (McCor-mack & Bown, 2009) | Impersonal | Interpretative | None | 2 | Yes | Controlled | 1 |
| Sonic Ecosystem (Bown & McCormack, 2010) | Impersonal | Interpretative | None | 2 | No | Random | 2 |
| Fluid space (Ji, 2012) | Personal | Explorative | Explicit | 5 | No | Random | 3 |
| Quorum Sens. (Chen & Hoyami, 2007) | Personal | Explorative | Implicit | 4 | No | Random | 3 |

(continued)

**Table 3** (continued)

| Work | Perspect. | User | Link | Mode | Det. | Acces. | Class |
|---|---|---|---|---|---|---|---|
| Filterscape (Eldridge & Dorin, 2009) | Impersonal | Interpretative | None | 2 | No | Random | 2 |
| Infinite game (Ji, 2012) | Personal | Explorative | Explicit | 5 | No | Random | 3 |
| Colour cycling (Eldridge et al., 2008) | Impersonal | Interpretative | None | 2 | No | Random | 1 |
| Funky Forest (Watson & Gobeille, 2007) | Personal | Explorative | Implicit | 5 | No | Random | 3 |
| xTNZ (Antunes & Leymarie, 2008) | Personal | Explorative | Explicit | 3 | No | Random | 2 |
| E-volver (Driessens and Verstappen, 2006) | Personal | Explorative | Explicit | 3 | No | Controlled | 1 |
| Plague (Dorin, 2006) | Personal | Explorative | Implicit | 3 | No | Random | 2 |
| Ambient Light (Spinster, 2007) | Personal | Interpretative | Explicit | 2 | No | Random | 2 |
| Lifedrop (Heudin, 2012) | Impersonal | Configurative | None | 2 | No | Random | 2 |
| Meniscus (Dorin, 2003) | Personal | Configurative | Explicit | 5 | No | Random | 2 |
| Black Sq. (Demos, 2012; Portway et al., 2004) | Impersonal | Interpretative | None | 4 | No | Random | 2 |
| Eden (McCor-mack, 2001) | Personal | Explorative | Implicit | 4 | No | Random | 2 |
| Biotica (Brown et al., 2001) | Personal | Explorative | Explicit | 3 | No | Random | 2 |
| Living Melod. (Dahlstedt & Nordahl, 2001) | Impersonal | Interpretative | None | 1 | No | Random | 2 |
| Listen. Skies (Berry et al., 2001) | Personal | Explorative | Explicit | 4 | No | Random | 2 |
| Iki Iki (Sommerer et al., 2001) | Personal | Configurative | Explicit | 3 | No | Random | 3 |
| Life spacies (Sommerer & Mignonneau, 2000) | Personal | Configurative | Implicit | 5 | No | Random | 2 |

(continued)

**Table 3** (continued)

| Work | Perspect. | User | Link | Mode | Det. | Acces. | Class |
|---|---|---|---|---|---|---|---|
| Garden of Ch. (Hutzler et al., 2000) | Personal | Configurative | Explicit | 4 | No | Random | 2 |
| NerveGarden (Damer et al., 2005) | Personal | Explorative | Explicit | 2 | No | Random | 2 |
| Nagual Exp. (Annunziato, 1998) | Impersonal | Interpretative | None | 1 | Yes | Controlled | 1 |
| Relazioni Emer. (Annunziato & Pierucci, 2000) | Personal | Configurative | Implicit | 3 | No | Random | 3 |
| Technos. (a) (Prophet, 1996) | Personal | Configurative | Explicit | 2 | No | Controlled | 2 |
| Technos. (b) (Prophet, 1996) | Personal | Configurative | Explicit | 2 | No | Controlled | 2 |
| EIDEA (Mitchell & Lovell, 1995) | Impersonal | Interpretative | None | 3 | No | Random | 3 |
| A-volve (Sommerer & Mignonneau, 1994) | Personal | Explorative | Explicit | 4 | No | Random | 2 |

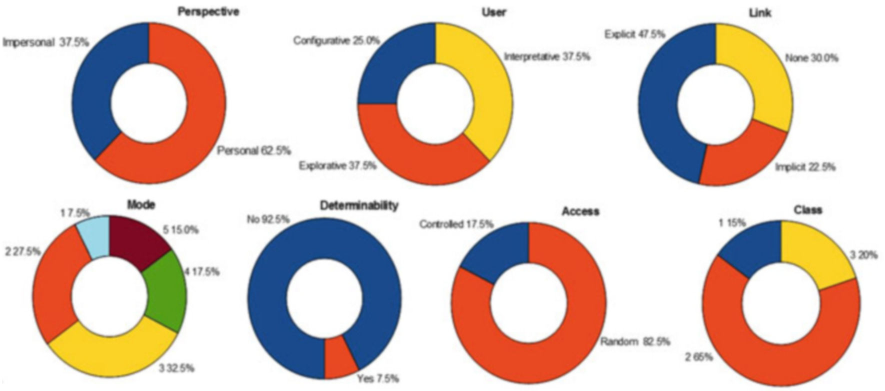


**Fig. 7** Diagrammatic summary of the interactivity of the works

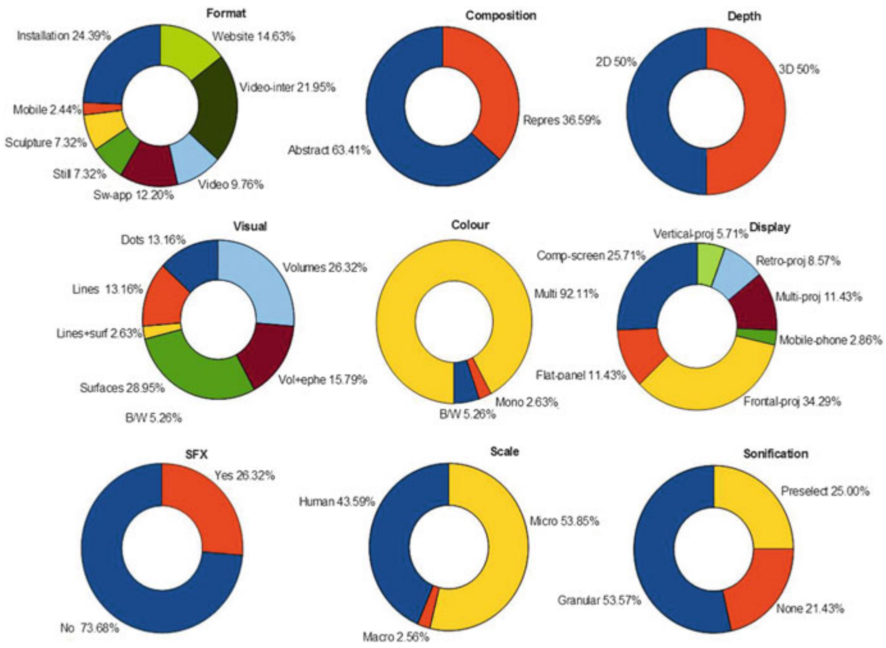


**Fig. 8** Diagrammatic summary of the formal presentation

restricted to operate only within set ranges.[1] For instance, if the programmer designs the system as composed by individuals represented by triangles, these will never become circles or take other geometrical forms. Having full access to non-determinability remains a “holy grail” of ALife: i.e. producing some open-ended systems which automatically generate and change their own rules of production (Mccormack, 2005).

In terms of the Linking variable, we notice that nearly half the works use explicit interaction devices such as a mouse in xTNZ, hands blocking a sensor’s view in Cycles, or wearing special goggles in Biotica. For nearly another quarter of the works the presence of the user is captured in a more discrete, implicit way (22 %). In terms of the Class variable, the majority of works (65 %) keep changing over time but not in a structural way (class #2), while a significant number exhibit more complex behaviors (class #3 at 22 %). As for the Mode variable, about 1/3 of the works explore simultaneously four or more of the properties analysed: visual, haptic, aural, movement from the user and perception of procedural qualities. In terms of the Perspective variable, for 62 % of the cases the user has a personal engagement with the story, either by creating a new creature (e.g. in AVolve (Sommerer & Mignonneau, 1994)), or adding food/energy (e.g. in Fluid Space (Ji, 2012)), or introducing a disease to the virtual world (e.g. in Pandemic (Dorin, 2012)) (Fig. 8).

[1] Note that most works (93 %) are not controlled; the only exceptions being works presented to the public as static pictures.

Finally, the Access variable provides us with a clear pattern that distinguishes CEs from other interactive media instances such as games, as a large majority (83 %) of the works represented here do not offer "levels" or hidden areas of the world that the user can activate by means of their actions.

## *3.3 Formal Parameters*

Table 4 presents the classification of the 40 works with regards to their formal variables making explicit their mode of presentation or exhibition.

The openness and plasticity of CEs is made explicit by our study. In the works analysed, while there is a similarity of methods used, this is combined with a great disparity of outcomes and heterogeneity in the Formats of production. The personal computer is not the privileged mode of operation, with only one third of the works taking the format of websites or software applications. Works exhibited in gallery spaces dominate the sample (nearly 70 %). From this large group, video projections and interactive-video clearly dominate. As a consequence, works tend to operate at human body (44 %) or smaller (micro) scales (54 %), and we notice that only one project in our sample exploits macro scales [Constellation (Dorin, 2009a)].

When it comes to the Composition, we took in consideration the representational scheme of choice composed of the shape, colour, the trace used, and the scale of the artefacts. Results suggest that there is a clear dominance of the abstract over the representational. This is not too surprising taking into consideration the agenda from ALife of "life as it could be". In terms of Visual Forms, dots and lines are rarely used in comparison to surfaces and volumes. Dots usually produce plasma-like looking works as a function of changing CE dynamics, whereas surfaces and volumes are the carriers of more traditional modes of representation, including the use of perspective and foreshortening.

As could be expected, the Color variable is dominated by multi-chromatic works over black and white or monochrome works. Surprisingly however, there is not much sophistication involved in the resulting visualizations. Authors seem to prefer solid forms rather than SFX such as blending textures or using complex graphics. This result might be somewhat biased due to the temporal scale of the particular sample under analysis, which includes a fair number of works from the 1990s and early 2000s when rendering sophisticated visuals in real time was comparatively much harder than in recent years.

When it comes to the Depth variable, there is no clear dominance of the use of 3D versus 2D. This might change in the future, as 3D technologies (of production and display) become more accessible.

The freedom of expression of CEs is again suggested when we consider the Sonification variable. Granular and synthesized sounds are used in 54 % of the works, while only 25 % use pre-selected more "naturalistic" sounds. Examples of sonification include the literal translation of CE dynamics [e.g. Time of Doubles (Ji, 2012; Wakefield, 2012)], abstract formulations [e.g. Living Melodies (Dahlstedt &

**Table 4** The formal classification of the 40 surveyed works

| Work | Format | Comp. | Visual | Depth | Color | SFX | Sonific. | Display | Scale |
|---|---|---|---|---|---|---|---|---|---|
| Codeform (McCormack, 2012) | Video | Repres | Volumes | 3D | Multi | Yes | Granular | Frontal-proj | Human |
| Swarmic-Art (Al-Rifaie & Bishop, 2013) | Website | Repres | Dots | 2D | B/W | No | Granular | Comp-screen | Micro |
| Untitled (Bornhofen et al., 2012) | Still | Abstract | Lines | 2D | Multi | No | None | NA | Micro |
| WisLM (a) (Antunes & Leymarie, 2013) | Video-inter | Repres | Volumes | 3D | Multi | No | Preselect | Frontal-proj | Micro |
| WisLM (b) (Antunes & Leymarie, 2013) | Website | Repres | Volumes | 3D | Multi | no | Preselect | Comp-screen | Micro |
| Time of Dbl (Ji, 2012; Wakefield, 2012) | Installation | Abstract | Vol + ephe | 3D | Multi | Yes | Granular | Multi-proj | Human |
| Pandemic (Dorin, 2012) | Installation | Abstract | Surfaces | 3D | Multi | No | Granular | Frontal-proj | Human |
| Vishnu's (Antunes & Leymarie, 2012) | Website | Repres | Volumes | 3D | Multi | No | Preselect | Comp-screen | Micro |
| EvoEco (Kowaliw et al., 2011) | Website | Abstract | Dots | 2D | Multi | No | None | Comp-screen | Micro |
| Cycles (Bisig & Unemi, 2010) | Sculpture | Abstract | Lines + surf | 2D | Multi | Yes | None | Vertical-proj | Micro |
| Sra Graca (Antunes & Leymarie, 2010) | Sw-app | Abstract | Vol + ephe | 3D | Multi | Yes | None | Comp-screen | Micro |
| Constellation (Dorin, 2009a) | Video | Repres | Surfaces | 2D | Multi | Yes | No | Retro-proj | Macro |
| Habitat (Dorin, 2009a) | Sw-app | Repres | Surfaces | 2D | Multi | No | Preselect | Comp-screen | Micro |
| Niches (McCormack & Bown, 2009) | Still | Abstract | Lines | 2D | Mono | No | None | NA | Micro |
| Sonic ecosystem (Bown & McCormack, 2010) | Sw-app | Abstract | NA | NA | NA | NA | Granular | NA | NA |
| Fluid space (Ji, 2012) | Installation | Abstract | Vol + ephe | 3D | Multi | Yes | Granular | Frontal-proj | Human |
| Quorum sens. (Chen & Hoyami, 2007) | Installation | Abstract | Vol + ephe | 3D | Multi | Yes | NA | Vertical-proj | Human |
| Filterscape (Eldridge & Dorin, 2009) | Sw-app | Abstract | NA | NA | NA | NA | Granular | NA | Human |
| Infinite game (Ji, 2012; Wakefield & Ji, 2009) | Installation | Abstract | Vol + ephe | 3D | Multi | Yes | Granular | Frontal-proj | Human |
| Colour cycling (Eldridge et al., 2008) | Video | Abstract | Dots | 2D | Multi | No | NA | Comp-screen | Micro |
| Funky forest (Watson & Gobeille, 2007) | Installation | Repres | Surfaces | 2D | Multi | No | Preselect | Multi-proj | Micro |
| xTNZ (Antunes & Leymarie, 2008) | Video-inter | Abstract | Vol + ephe | 3D | Multi | Yes | Preselect | Frontal-proj | Micro |
| E-volver (Driessens and Verstappen, 2006) | Video-inter | Abstract | Dots | 2D | Multi | No | NA | Flat-panel | Micro |
| Plague (Dorin, 2006) | Installation | Abstract | Surfaces | 3D | Multi | No | Granular | Frontal-proj | Human |
| Ambient light (Spinster, 2007) | Installation | Abstract | Surfaces | 2D | Multi | No | NA | Flat-panel | Micro |

(continued)

**Table 4** (continued)

| Work | Format | Comp. | Visual | Depth | Color | SFX | Sonific. | Display | Scale |
|---|---|---|---|---|---|---|---|---|---|
| Lifedrop (Heudin, 2012) | Website | Repres | Lines | 2D | Multi | No | NA | Comp-screen | Micro |
| Meniscus (Dorin, 2003) | Video-inter | Abstract | Surfaces | 2D | Multi | No | NA | Flat-panel | Micro |
| BlkScholes (Demos, 2012; Portway et al., 2004) | Installation | Abstract | Dots | 2D | Multi | No | NA | Multi-proj | Human |
| Eden (McCormack, 2001) | Installation | Abstract | Surfaces | 2D | Multi | No | Granular | Multi-proj | Human |
| Biotica (Brown et al., 2001) | Sculpture | Abstract | Volumes | 3D | Multi | No | Granular | Retro-proj | Human |
| LivingMelodies (Dahlstedt & Nordahl, 2001) | Sw-app | Abstract | NA | NA | NA | NA | Granular | NA | NA |
| ListeningSkies (Berry et al., 2001) | Video-inter | Represt | Surfaces | 3D | Multi | No | Granular | Frontal-proj | Human |
| Iki Iki (Sommerer et al., 2001) | Mobile | Abstract | Surfaces | 2D | Multi | No | NA | Mobile-phone | Micro |
| Garden of Ch. (Hutzler et al., 2000) | Video-inter | Abstract | Surfaces | 2D | Multi | No | Preselect | Frontal-proj | Micro |
| Life Spacies (Sommerer & Mignonneau, 2000) | Video-inter | Repres | Volumes | 3D | Multi | No | NA | Frontal-proj | Human |
| NerveGarden (Damer et al., 2005) | Website | Repres | Volumes | 3D | Multi | No | NA | Comp-screen | Micro |
| Nagual Exp. (Annunziato, 1998) | Still | Abstract | Lines | 2D | B/W | No | NA | NA | micro |
| Relazioni Emerg (Annunziato & Pierucci, 2000) | Video-inter | Abstract | Lines | 2D | Multi | No | Granular | Retro-proj | Human |
| Technosph. (a) (Prophet, 1996) | Video-inter | Repres | Volumes | 3D | Multi | No | NA | Frontal-proj | Human |
| EIDEA (Mitchell & Lovell, 1995) | Video | Repres | Volumes | 3D | Multi | Yes | Granular | Frontal-proj | Human |
| A-volve (Sommerer & Mignonneau, 1994) | Sculpture | Repres | Volumes | 3D | Multi | No | NA | Flat-panel | Human |

Nordahl, 2001)], or having visuals being entirely secondary while the focus of the work is on the sound generated [e.g. Filterscape (Eldridge & Dorin, 2009)]. Surprising is the fact that there is no sonification at all in a large number of the works (22 %), as reported in associated papers, blogs or websites. It is also worth mentioning that some works use sounds independently from the CE's dynamics [such as in WisLM (Antunes, 2012; Antunes & Leymarie, 2013) and Vishnu's (Antunes & Leymarie, 2012)].

## 4 Discussion and Future Perspectives

Since the early 1990s artists have been experimenting with ways in which Computational Ecosystems (CEs), as a toolbox and aesthetical framework, could expand and enhance their praxis.[2] The collaboration between artists and scientists within the domain of ALife has produced new art forms, new visual languages, and new ways of relating life processes to aesthetics. And as new forms emerge, artists are finding even more creative, exciting applications. These are presented in a diversity of forms: from single-channel videos screened on a gallery monitor or video installations, to the intimacy of the personal-computer. Challenging traditional ideas of art and science, these artists use the technology as moving canvases and sculptures for often surreal, sometimes self-indulgent, usually powerful art works. They expand the visual vocabulary and force viewers to think about the relationship between art and science in a new way.

### *4.1 CEs as Art Forms*

The use of CEs as an art producing medium establishes a dialogue with pictorial and representational traditions. It inherits methods and canons which have been in practice for centuries and now manifest themselves in structuring new works. For instance, the canvas is slowly and patiently filled with "virtual ink" in Annunziato's works (Annunziato, 1998; Annunziato & Pierucci, 2000). Each agent on the canvas is a virtual drawing brush which traces virtual ink until it reaches another agent at which point it stops its activity and "dies". Annunziato's methodology echoes the processes involved in traditional drawing and painting: layers of ink are added to the canvas in a material composition of juxtapositions, accumulation and masking.

[2] We have to keep in mind that the sample scrutinized here illustrates about two decades of practice where we have witnessed an immense technological evolution. As a consequence, works from the first decade might exhibit features that are systematically distinct from those of the second. The ability to create (or make use of) certain formal properties or interactive features might not have existed earlier and we should keep this in mind. A more in-depth analysis would be needed to clarify this point.

A similar procedure is followed in Driessens and Verstappens's works where the canvas is akin a memory of spatial changes (Driessens and Verstappen, 2006). These works portrait the spatial dynamics of the community of agents working together on the canvas exhibited in a gallery space. Drawings result from changes in concentration and density in the community. However, in an interactive process visitors can destroy whole populations of agents whose drawings they do not like or care for. With the help of a touch screen, they can choose a new orientation for the work from a set of possible and logical continuations which can be initiated from the present configuration. In a process of subtraction, similar to the one when material is carved out from a marble piece to let emerge a sculpture, Driessens and Verstappen's audience removes raw possibilities from a chunk of virtual potentials to let the work progress in a possibly more likeable direction. This operative arithmetic of addition and subtraction forms the essence of the dynamics of this "vivid painting in motion" as Lioret describes it (Lioret, 2012).

Other classic representational strategies include the omnipresent duality between interior and exterior spaces. This is emphasized in the tradition of visual arts by the frame surrounding the painting or photograph, or the pedestal supporting and elevating the vase or sculpture; it echoes the classical idea that the human stands outside, in the exterior space, to observe the artefact sitting in the interior space, the focus of our attention. Most works we analysed share this dichotomy by emphasising the computational nature of the artefacts produced and the window (or screen) paradigm which is still dominant. This dichotomy is used and integrated with contextual advantage in the narratives of works such as Senhora da Graça (Antunes & Leymarie, 2010) or EIDEA (Mitchell & Lovell, 1995) where the interior/exterior duality is emphasised by contrasting the "natural outlooks" of an exterior space from the mechanistic intricacies of the artefact production.

However, artists making "vivid painting in motion" do not constrain their practice to established processes and methods inherited from classical art despite being greatly influenced by these. The artefacts produced owe much as well to contemporary art forms such as video and installation art. Challenging the interior/exterior dichotomy, works such as Pandemic (Dorin, 2012), Eden (McCormack, 2001) and in general works in the format of installations try to blur the differences between the virtual and tangible spaces. These works combine a CE with sensing techniques, often adapted from computer vision, to capture the audience's location in a subtle way. For instance, the physical presence of the audience in Eden energizes a virtual world. The audience becomes the center of attention of the virtual creatures who sing to call their attention and attract them in order to obtain more energy. A similar approach was followed in the Artificial Nature series where the body's shape and volumetric information is captured and transformed into energetic particles in a virtual space (Wakefield & Ji, 2009). The audience does not always play a positive role: in Pandemic for instance, the avatars of the members of the audience become a spreading disease (Dorin, 2012).

We pointed out earlier that the generative powers of a CE rely on the gradual and cumulative effects of the changes produced by the dynamics of the autonomous elementary units of the system. Time is omnipresent. This is an essential component for any CE's operation. It is a structuring and definite variable, and works produced using CEs are naturally affiliated with the traditions of kinetic art.

As our study demonstrates, works tend to be abstract in their appearance. Members of the virtual population are represented by dots (Driessens and Verstappen, 2006), lines (Annunziato, 1998), surface shapes (Dorin, 2006), or 3D volumes (Antunes & Leymarie, 2010). The data illustrates the openness of the methodology and none of these forms dominates the others. In some instances we have outcomes with visuals rendered having plasma-like qualities (Driessens and Verstappen, 2006), whereas in others we have communities of 3D avatars walking in virtual worlds (Antunes, 2012; Antunes & Leymarie, 2013). However only in a few cases does the work represent realistically the appearance of existing life-forms. Abstraction (of form) is dominant while the motto "life-as-it-could" inherited from ALife reigns over most of the spectrum of this praxis.

Nevertheless, CEs as used in EvoArt remain representational. ALife art owes much to the tradition of "organicism" with its agenda and interest in representations of life. And while ALife art is not necessarily representational in the *appearance* of life forms, it remains in the way it simulates how life operates. This has been pointed out before, in particular by Mitchell Whitelaw (Whitelaw, 2004). This is indeed a fundamental aspect that is common to all the artefacts surveyed in our study. Here it might be helpful to recall Rosalind Krauss when she questions the modernist medium-specificity in the arts. She argues the medium is not reducible as the "specific material support for a traditional aesthetic genre" (Krauss, 2011). This expanded notion of the medium that she is proposing, detached from the technical substratum, is rather grounded on a set of historically situated praxis, or what she calls the "technical support".[3] EvoArt provides examples of an artistic praxis where it is not mainly the technological medium that constitutes or defines the aesthetics: it is the ideas implemented that are important rather than the means of implementing them. The technical support of EvoArt is the set of ideas and methods informing this particular artistic praxis, including artificial life, cyberculture, systems theory, cybernetics, and the CE as a generative technique. The generative technology remains open and may be used for the purpose of varied artistic agendas as confirmed by our survey.

[3] The purist modernist tradition dwells much around the medium, of playing with the properties of the medium. Consider painting: a modernist will ask what can be done with painting, how far can we take it, use its material constraints; and then follows the questioning of what are the "materials of painting". Krauss contests that idea and argues that it is the "technical support" one should consider, which is not strictly rooted in the properties of the medium, but rather on the set of ideas that inform the practice. For example, the painter might still be working with canvas and ink, but the work is subordinated to an idea, a subject and this is what becomes central. So for instance Ed Rusha is working with the subculture of Los Angeles, the automobile, its slang, the movie-stars (Krauss, 2011).


**Fig. 9** The versatility of CEs: (**a**) Stills from Vishnu's Dance of Life and Death, a generative choreography in a virtual environment (Antunes & Leymarie, 2012); The sequences of gestures and movements are created in unexpected ways by reflecting the interior dynamics and workings of a CE in operation; © Antunes & Leymarie, 2012. (**b**) Where is Lourenço Marques? a virtual world where a population of gregarious humanoids is animated by a CE (Antunes, 2012; Antunes & Leymarie, 2013); © Antunes & Leymarie, 2012. (**c**) Jon McCormack's Eden (2004, detail), evolutionary ecosystem installation using multiple projectors and screens, with "creatures" improving their "singing" to attract visitors to their vicinity; © 2004 Jon McCormack (McCormack, 2001). (**d**) In Cycles' installation, the hand of the visitor is used as display; © 2009 Daniel Bisig (Bisig & Unemi, 2010). (**e**) Detail of Pandemic (Dorin, 2012), an installation where creatures spread among themselves colourful "diseases" brought by the human visitors of the installation; © Alan Dorin, 2012. (**f**) Drawing produced by swarmic entities while searching for "energy" bits specially located in the canvas (Al-Rifaie & Bishop, 2013); © Al-Rifaie & Bishop, 2013

### 4.2 CEs and Virtual Worlds

How do CEs inform Virtual Worlds? Based on the survey we conducted we can shortlist a number of characteristics and directions to exploit and explore further: (i) first and foremost is the autonomy of the system, which is formed by communities of agents, self-motivated and with various and varying behaviors [e.g. Eden (McCormack, 2001)]; (ii) moreover, such agents forming communities can have multiple representations and change over time (in the audible and/or visual domains)—such as being a youth in the early stages of a performance and become later an adult [e.g. xTNZ (Antunes & Leymarie, 2008)]; (iii) additionally, as the first genre of EvoArt implies, agents can evolve over generations, by means of genetics and evolution via natural selection [e.g. Senhora da Graça (Antunes & Leymarie, 2010)]; (iv) CEs can be modulated by user inputs, such as when agents are added and removed by the user's actions, who can further interact with them and their resources or even modify their genetic properties [e.g. A-Volve (Sommerer & Mignonneau, 1994)[; (v) CEs can be controlled by external sources, such as weather conditions (Hutzler et al., 2000) or stock market exchange data [e.g. Black Sholes (Portway et al., 2004; Demos, 2012)].

As discussed previously, a critical aspect of a CE lies in its plasticity. As our study shows, CEs form a basis which is current in the production of a diverse and wide range of artistic outcomes. Virtual World developers can rely on this basis and incorporate CEs in their methodology and toolbox of proven technologies and art praxis. Examples of CEs combined with Virtual Worlds also illustrate the potentials of bringing together these two realms. Examples range from the abstract "vivid painting in motion" (Lioret, 2012), such as in Cycles (Bisig & Unemi, 2010), to food-chains composed of autonomous NPCs acting as herbivores or carnivores and roaming in a virtual space [e.g. in Technosphere (Prophet, 1996)], to the animation of performing and improvising dancing avatars (e.g. in Vishnu's Dance of Life and Death (Antunes & Leymarie, 2012), Fig. 9a), to talkative gregarious humanoid avatars inhabiting a lost city (e.g. in Where is Lourenço Marques? (Antunes, 2012; Antunes & Leymarie, 2013), Fig. 9b).

## 5 Conclusion

We have looked at the context and features of artworks produced with CEs, as these have been presented to public audiences over the last two decades. The core of our study is a survey on the structure and attributes of artworks produced using a CE as framework, covering 40 published works through 20 years of praxis. We discussed and compared these works in terms of three categories of variables (contextual, interactivity and format). In terms of Contextual variables, our analysis shows that a large majority of works operate autonomously, with some inputs provided by the audience and are focused around the visualisation of life processes. In terms of

Interactivity, almost all works involve visualisation, sonification or a combination thereof, and nearly half the projects involve the audience in influencing CEs' outcomes. Finally, in terms of Formal variables, a majority of works are exhibited in gallery spaces, and are set at the human scale (rather than say, the architectural scale). Forms and geometries used tend to be abstract rather than photo-realistic or purely representational.

Future projects could demarcate themselves from the works we surveyed by in particular: (i) further explore the use of external inputs (rather than mostly having an audience influence a CE's outcomes), (ii) allow users to reconfigure a CE's settings and evolution, (iii) give more control to users in accessing hidden levels or yet undiscovered areas of a Virtual World (and maintain interest), alike in the design of commercial games, (iv) use advances in real time graphics, integrate more special effects, and perhaps explore further the use of 3D visualisations (e.g. with autostereoscopy and new wearable AR and VR systems such as Google glasses and their descendants), (v) produce multimedia works which integrate more intimately the different modalities, in particular the visual and aural (which tend to be left independent in their production), and also integrate haptics and gestures thanks to recent and foreseeable developments in hardware and software, (vi) favour and explore further the dimensions of the environment, society, the political or the economy, rather than the prevalent life process referential, (vii) promote works to the macro scales, such as the architectural (e.g. projecting on the facades of buildings and monuments) or urban (e.g. using mobile platforms).

In summary, CEs provide a rich framework in support of EvoArt which has been explored in multiple formats and as part of diverse artistic agendas. By studying these artefacts we can identify a number of techniques and approaches which might inform the development of future Virtual Worlds, and augment these with evolutionary mechanisms of natural selection and genetics, use CEs to create generative soundscapes, or even use CEs in Virtual Worlds as abstract generative engines and explore their dynamics as a way to animate agents with unique, even human-like, behaviors (Antunes & Leymarie, 2013).

## References

Aarseth, E. (1997). *Cybertext: Perspectives on ergodic literature*. Baltimore, MD: The Johns Hopkins University Press.

Al-Rifaie, M., & Bishop, M. (2013). Swarmic sketches deploy attention mechanism. In P. Machado, J. McDermott, & A. Carballal (Eds.), *Proceedings of the Second International Conference on Evolutionary and Biologically Inspired Music, Sound, Art and Design, Evomusart 2013* (Vol. 7834, pp. 85–96). Heidelberg: Springer.

Annunziato, M. (1998). The Nagual experiment. In *Proceedings of the First International Conference on Generative Art* (pp. 241–250).

Annunziato, M., & Pierucci, P. (2000). Towards artificial societies. In *Proceedings of the Third International Conference on Generative Art*.

Antunes, R. F. (2012). Where is Lourenço Marques? A mosaic of voices in a 3D virtual world. *Leonardo Electronic Almanac (Touch and Go), 18*(3), 114–121.

Antunes, R. (2014). *On computational ecosystems in media arts*. PhD thesis, Goldsmiths College, University of London.

Antunes, R. F., & Leymarie, F. F. (2008). xTNZ-an evolutionary three-dimensional ecosystem. In A. Barbosa (Ed.), *Proceedings of the Fourth International Conference on Digital Arts, Artech2008* (pp. 201–204).

Antunes, R. F., & Leymarie, F. F. (2010). Epigenetics as aesthetic instrument in a generative virtual ecosystem. In L. Valbom (Ed.), *Proceedings of the Fifth International Conference on Digital Art Artech 2010* (pp. 172–176).

Antunes, R. F., & Leymarie, F. F. (2012). Generative choreography: Animating in real time dancing avatars. In P. Machado, J. Romero, & A. Carballal (Eds.), *Proceedings of the First International Conference on Evolutionary and Biologically Inspired Music, Sound, Art and Design, Evomusart 2012* (pp. 1–10).

Antunes, R. F., & Leymarie, F. F. (2013). Real-time behavioral animation of humanoid non-player characters with a computational ecosystem. In R. A. et al. (Ed.), *13th Conference on Intelligent Virtual Agents (iva 2013), lnai 8108* (pp. 382–395). Heidelberg:Springer.

Arts, E. (2009). *Second life masterpieces—Starax Statosky: Second Life Giotto*. Retrieved from http://sichelseifert.wordpress.com/2009/01/05/starax-statosky-second-life-giotto/

Bentley, P., & Corne, D. (2002). *Creative evolutionary systems*. San Diego, CA: Academic.

Berry, R., Rungsarityotin, W., & Dorin, A. (2001). Unfinished symphonies—songs of 3 1\2 worlds. In B. et al (Ed.), *Ecal 2001 artificial life models for musical applications* (pp. 51–64). Konferensbidrag

Bisig, D., & Unemi, T. (2010). Cycles—blending natural and artificial properties in a generative artwork. In *Proceedings of the xiii Generative Art Conference. Milano, Italy* (pp. 140–154). Retrieved from http://lab30.de/2010/en/exhibition/97

Boden, M. A., & Edmonds, E. A. (2009). What is generative art? *Digital Creativity, 20*(1 & 2), 21–46.

Bornhofen, S., Heudin, J., Lioret, A., & Torrel, J. (Eds.). (2012). *Virtual worlds: Artificial ecosystems and digital art exploration*. Paris: Science ebooks.

Bornhofen, S., Gardeux, V., & Machizaud, A. (2012). From swarm art toward ecosystem art. *International Journal of Swarm Intelligence Research, 3*(3), 18.

Bown, O., & McCormack, J. (2010). Taming nature: Tapping the creative potential of ecosystem models in the arts. *Digital Creativity, 21*(4), 215–231.

Brown, R., Aleksander, I., MacKenzie, J., & Faith, J. (2001). *Biotica: Art, emergence and artificial life*. London: Art Books International.

Carvalhais, M. (2010). Towards a model for artificial aesthetics. In *Proceedings of ga2010—xiii Generative Art Conference.*

Chen, C.-Y., & Hoyami, J.-C. (2007). Autonomous systems for interactive digital art. In *Tenth Generative Art Conference ga2007.*

Dahlstedt, P., & Nordahl, M. G. (2001, June). *Living melodies: Coevolution of sonic communication* 34(3)

Damer, B., Marcelo, K., Revi, F., Furmanski, T., & Laurel, C. (2005). Nerve garden: Germinating biological metaphors in net-based virtual worlds. In A. Adamatzky & M. Komosinski (Eds.), *Artificial life models in software* (pp. 67–80). London: Springer.

Demos, T. J. (2012, April). Art after nature. *Artforum*, pp. 191–198.

Dorin, A. (2003). *Meniscus—exhibited at the Experimenta House of Tomorrow*. Retrieved 5 Sept—3 Oct 2003, from http://www.csse.monash.edu.au/ aland/meniscus.html

Dorin, A. (2005). Artificial life, death and epidemics in evolutionary, generative electronic art. In F. Rothlauf et al. (Ed.), *Proceedings of the Third European Workshop on Evolutionary Music and Art, Applications of Evolutionary Computing: Evoworkshops* (pp. 448–457). Berlin, Heidelberg: Springer.

Dorin, A. (2006). *Plague, exhibited at Satellite, Australian Pavillion, for Shanghai Bienalle*. Retrieved September 3–27, 2006, from http://www.csse.monash.edu.au/aland/plague.html

Dorin, A. (2009a). *Constellation—exhibited at Biotope, Cube 37 Gallery, Frankston, Victoria, Australia. Curated by CEMA*. Retrieved 13 July–9 August, from http://www.csse.monash.edu.au/aland/constellation.html

Dorin, A. (2009b). Habitat: Engineering in a simulated audible ecosystem. In M. Giacobini et al. (Eds.), *Applications of evolutionary computing* (Vol. 5484, pp. 488–497). Berlin, Heidelberg: Springer.

Dorin, A. (2012). *Pandemic—generative software installation, Exhibited: Bouillants 4, Vern-sur-Seiche, Brittany, France, Gaetan Allin and Laurent Dupuis (artistic directors)*, 22 April–20 May

Driessens and Verstappen. (2006). *E-volver—exhibited at the new Onderzoeksgebouw (research building) of the Leiden University Medical Center, in Amsterdam, from*http://classic.skor.nl/page/2429/nl?lang=en

Eldridge, A., & Dorin, A. (2009). Filterscape: Energy recycling in a creative ecosystem. In M. Gia-cobini (Ed.), *Proceeding of Evoworkshops'09 Proceedings of the Evoworkshops 2009 on Applications of Evolutionary Computing* (pp. 508–517). Heidelberg: Springer.

Eldridge, A., Dorin, A., & McCormack, J. (2008). Manipulating artificial ecosystems. In M. Giacobini et al. (Eds.), *Applications of evolutionary computing* (Vol. 4974, pp. 392–401). Berlin, Heidelberg: Springer.

Heudin, J.-C. (2012). Lifedrop: A drop of life on the web. In S. Bornhofen, J. Heudin, A. Lioret, & J. Torrel (Eds.), *Virtual worlds: Artificial ecosystems and digital art exploration* (pp. 79–98). Paris: Science ebooks.

Hutzler, G., Gortais, B., & Drogoul, A. (2000). The garden of chances: A visual ecosystem. *Leonardo, 33*, 101–106. MIT Press Journals.

Ji, H. (2012). *Artificial natures: Creating nature-like aesthetic experiences through immersive artificial life worlds*. Ph.D. Dissertation, University of California, Santa Barbara.

Ji, H., & Wakefield, G. (2012). Virtual world-making in an interactive art installation: Time of doubles. In S. Bornhofen, J. Heudin, A. Lioret, & J. Torrel (Eds.), *Virtual worlds: Artificial ecosystems and digital art exploration* (pp. 53–70). Paris: Science ebooks.

Kowaliw, T., McCormack, J., & Dorin, A. (2011, April). An interactive electronic art system based on artificial ecosystemics. In *2011 I.E. Symposium on Artificial life (alife)* (pp. 162–169). doi: 10.1109/AL-IFE.2011.5954645

Krauss, R. E. (2011). *Under blue cup*. Cambridge, MA: MIT Press.

Lambert, N., Latham, W., & Leymarie, F. F. (2013). The emergence and growth of evolutionary art 1980–1993. *Leonardo, 46*(4), 367–375.

Latham, W. (1989). Form synth: The rule-based evolution of complex forms from geometric primitives. In J. Lansdown & R. A. Earnshaw (Eds.), *Computers in art, design and animation* (pp. 80–108). New York: Springer.

Lenton, T. M., & Lovelock, J. E. (2001). Daisyworld revisited: Quantifying biological effects on planetary self-regulation. *Tellus B, 53*(3), 288–305.

Lioret, A. (2012). Artificial life creation for cinema. In S. Bornhofen, J. Heudin, A. Lioret, & J. Torrel (Eds.), *Virtual worlds: Artificial ecosystems and digital art exploration* (pp. 23–38). Paris: Science ebooks.

McCormack, J. (1994). TURBULENCE an interactive installation exploring artificial life. In *Visual Proceedings of ACM Siggraph 94* (pp. 182–183). Orlando, FL: Academic Press

McCormack, J. (2001). Eden: An evolutionary sonic ecosystem. In J. Sosik & P. Kelemen (Eds.), *Lecture notes in artificial intelligence* (Vol. 2159, advances in artificial life, pp. 133–142). Berlin: Springer.

Mccormack, J. (2005). Open problems in evolutionary music and art. In F. Rothlauf et al. (Eds.), *Applications of evolutionary computing, (evomusart 2005)* (pp. 428–436). Berlin: Springer.

McCormack, J. (2012). *CodeForm, Virtual Ecosystem of Artificial Life, Commission for the Ars Electronica Museum*, Linz, Austria, from http://jonmccormack.info/~jonmc/sa/artworks/codeform/

McCormack, J., & Bown, O. (2009). Life's what you make: Niche construction and evolutionary art. In M. Giacobini et al. (Eds.), *EvoWorkshops* (LNCS 5484, pp. 528–537). Berlin: Springer.
Mitchell, J. D., & Lovell, R. E. (1995). Environment for the interactive design of emergent art. In *Isea 95: Sixth international symposium on electronic arts* (pp. 17–21). Montreal, Canada
Portway, J., Autogena, L., Hoile, C., & Riley, T. (2004). *Black shoals: Stock Market Planetarium*, from www.blackshoals.net
Prophet, J. (1996). Sublime ecologies and artistic endeavors: Artificial life and interactivity in the online project "TechnoSphere". *Leonardo, 29*(5), 339–344. Retrieved from http://www.jstor.org/stable/1576397.
Railsback, S. F., & Grimm, V. (2011). *Agent-based and individual-based modeling: A practical introduction*. Princeton, NJ: Princeton University Press.
Ray, T. S. (1995). An evolutionary approach to synthetic biology: Zen and the art of creating life. Artificial Life 1(1/2): 179–209. In C. G. Langton (Ed.), *Artificial life, an overview* (pp. 179–209). The MIT Press.
Romero, J., & Machado, P. (Eds.). (2007). *The art of artificial evolution: A handbook on evolutionary art and music*. Berlin: Springer.
Saruwatari, T., Toqunaga, Y., & Hoshino, T. (1994). ADIVERSITY: Stepping up trophic levels. In R. A. Brooks & P. Maes (Eds.), *Proceedings of the Fourth International Workshop on the Synthesis and Simulation of Living Systems* (pp. 424–429).
Sommerer, C., & Mignonneau, L. (1994). A-Volve: A real-time interactive environment. In *ACM Siggraph Visual Proceedings* (pp. 172–173).
Sommerer, C., & Mignonneau, L. (2000). Life Spacies II. In G. Stocker & C. Schöpf (Eds.), *Ars Electronica 2000 Next Sex* (p. 392). Vienna, New York: Springer.
Sommerer, C., Mignonneau, L., & Lopez-Gulliver, R. (2001). IKI-IKI Phone—A multiuser Alife art game for mobile phones. In *IEEEE International Conference on Multimedia and Expo (ICME),* Tokyo, Japan (pp. 152–155).
Spinster, A. (2007). *Exhibited at down to Earth, Oxford House Art (Oh! Art)*, from http://www.turbulence.org/blog/archives/002602.html
Todd, S., & Latham, W. (1992). *Evolutionary art and computers*. San Diego, CA: Academic Press.
Ventrella, J. (2005). GenePool: Exploring the interaction between natural selection and sexual selection. In A. Adamatzky & M. Komosinski (Eds.), *Artificial life models in software* (pp. 81–96). Berlin: Springer. Retrieved from http://www.ventrella.com/alife/genepool.pdf.
Wakefield, G. (2012). *Real-time meta-programming for open-ended computational arts*. Ph.D. Dissertation, University of California, Santa Barbara.
Wakefield, G., & Ji, H. (2009). Artificial nature: Immersive world making. In R. A. Brooks & P. Maes (Eds.), *Applications of evolutionary computing* (Lncs 5484, pp. 377–381). Berlin: Springer.
Watson, T., & Gobeille, E. (2007). *Exhibited at DigiPlaySpace*, from http://www.theowatson.com/sitedocs/work.php?id=41
Watson, A. J., & Lovelock, J. E. (1983). Biological homeostasis of the global environment: The parable of Daisyworld. *Tellus B, 35*(4), 286–289.
Whitelaw, M. (2004). *Metacreation: Art and artificial life*. Cambridge, MA: MIT Press.
Yaeger, L. (1994). Computational genetics, physiology, metabolism, neural systems, learning, vision, and behavior on Polyworld: Life in a new context. In C. Langton (Ed.), *Artificial life III, Santa Fe Institute Studies in the Sciences of Complexity* (Vol. xvii, pp. 263–298). Reading, MA: Addison-Wesley.

# Finding Healthcare Support in Online Communities: An Exploration of the Evolution and Efficacy of Virtual Support Groups

**Donna Z. Davis and Willemien Calitz**

## 1 Introduction

Technology has long been blamed for contributing to the breakdown of community and social capital. Whether it be the advent of airconditioning and automatic garage door openers that changed the way we engaged with neighbors (Warren, 1978) or television viewership replacing family time (Putnam, 2000), researchers have pointed to technology as an isolating force (Turkle, 2011). Yet, for many people, social media have provided a sense of place and a way to connect when physical world circumstances and relationships may be limited by geography, emotional distance or access to professionals and peer support.

3D3C virtual worlds may perhaps be one of the most engaging and complete forms of social media as they provide both synchronous and asynchrous communication via text messaging, voice enabled technology, file sharing and more, enhanced by immersion in a visually stimulating and interactive 3D environment. Healthcare support communities represent a population who may gain significantly from the ability to connect via these 3D3C worlds. This chapter will explore the evolution and efficacy of support groups in 3-D immersive virtual worlds and discuss one such support group in Second Life. The literature reveals the importance of social support in general; of finding support online; and the strengths and weaknesses in the current technologies that offer healthcare support groups in 3-D virtual environments.

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# 2 Understanding the Role of Social Support

People who live with disability, chronic illness or mental illness face a growing risk of isolation even though the benefits of social support have been well documented. Research exploring these benefits recognize greater resilience among individuals facing stressful life circumstances such as chronic or life threatening illness while conversely, "lack of social support contributes to physical illness and psychopathology" (Schaefer, Coyne, & Lazarus, 1981, p. 382). Social support provided through friends, families, communities and organizations improves self-esteem and depression. Specifically, as Symister and Friend (2003) explain, "social support is a central concept in healthy psychology that has important practical implications for patients adjusting to chronic illness" (p. 123).

Schaefer et al. (1981) identified three types of perceived social support, including tangible, emotional and informational. Emotional support represents intimacy and attachment, tangible support includes direct aid such as money or providing service such as caregiving, and informational support represents actions such as providing advice or feedback.

## 2.1 Connection and Isolation

In a study of patients with end-stage renal disease and rheumatoid arthritis patients, Symister and Friend (2003) further explicated social support among chronically ill and found a dependence on family and friends for "esteem validation, as they struggle with the stresses and incapacities caused by their illness, and for tangible supports in dealing with the medical and other routines of their everyday lives" (p. 123). They concluded that esteem support is especially valuable when illness can affect self-worth, consequently resulting in depression, which in turn can decrease social support.

They found that "Feeling connected and socially integrated through frequent contact may be a form of social regulation which helps chronically ill patients maintain positive mood and optimism. Lack of belongingness may result in feelings of social isolation, loneliness, and depersonalization (low self-esteem), which may promote negative mood and hopelessness" (p. 127).

Considering the critical role that belongingness plays in the wellbeing of the vulnerable populations of the chronically ill, increased recognition of the potential use of online social networks to build social support warrants further review. However, early research following the effects of social technology reported the paradoxical relationship of social technology resulting in isolation, depression and a lack of meaningful relationships (Heim, 1991; Kraut et al., 1998; Nie & Erbring, 2000; Turkle, 1984, 1996) and has been supported more recently by Turkle (2010). Yet, debate continues over the positive and negative impacts of social technology. For example, Ellison, Steinfield, and Lampe (2007) identified a concept of "maintained social capital," referring to "online network tools which enable individuals to keep in touch with a social network after physically disconnecting from it" (p. 1).

## 2.2 *Evolution of Communities of Support*

Regardless of perspective of social consequences, online communities continue to form. Preece and Maloney-Krichmar (2003) define online communities as a group of people who interact in a virtual environment with a purpose, supported by technology and guided by norms and policies. They also identified different qualities that shape online communities including that: they may or may not have a physical presence; may differ in purpose; are supported by varying types of software; and vary in size, age, stage in lifecycle, culture and governance.

Haythornthwaite and Kendall (2010) explain the role of the Internet in defining communities, saying "Early on, the question was whether community could exist online; now the question may be whether it can exist without online" (p. 1086). Their collection of literature repeatedly suggests that online relationships could be strengthened rather than weakened via online interactions and that close, personal ties are built and maintained through digital technologies.

These ties are perceived as important to the overall health of the online community. According to Ren et al. (2012), the strength of online communities resides in their ability to develop member attachment. In their 6-month field experiment, they found that when participants were exposed to community features that fostered attachment such as access to profiles and repeated exposure to group activities, the study participants visited the community more frequently. Additionally, they found newcomers to the community embraced features that fostered interpersonal relationships. This finding reinforced prior research that suggests, "that member participation and retention depends on member attachment, which is cultivated by connecting members with topics of their interest and like-minded others

(Preece, 2000).” Particularly, they found that members with strong attachment to their online communities were also the ones who provided value to others by their ability to answer their questions and concerns.

## 3 Online Communities for Social Support

### *3.1 Access to Shared Experiences*

Regardless of platform, there are many common attributes among online support communities. For example, in their research of online patient support communities Preece and Maloney-Krichmar (2003) echo prior research on the role of social support and found these communities build a level of empathy that “may encourage strong relationships to develop making these communities some of the most important on the Internet” (p. 35). Likewise, in an online and offline study specific to cancer support communities, Turner, Grube and Meyers concluded that the “Online support members may be less concerned with preserving face and may communicate support in a more ‘bald on record’ way” (p. 246), a quality in the communication that patients wanted. These benefits were also recognized in the work of White and Dorman (2001) whose study of online support as a function of health education asserted “These support groups have certain benefits for users who may not be able to or do not have the desire to attend face-to-face sessions” (p. 693).

As the research extended to virtual worlds, Norris (2009) systematic review of the growth of online support groups in virtual world environments offered comparisons of online and offline support groups, revealing mixed results. Citing numerous studies that found potential strengths in online support groups, he concluded that the efficacy of online support groups still had yet to be established.

Although Norris was looking exclusively at 3-D virtual worlds as the technological platform for these support groups, the author identified the complexity of online virtual worlds as a barrier to understanding what encourages or inhibits effective group formation. Norris suggests further study of health care support groups in virtual worlds “may allow one to tailor virtual worlds to successfully address particular healthcare issues.” (p. 18).

## 4 Support Groups in Virtual Worlds

### *4.1 Emerging Uses of Virtual Worlds*

As evidenced in the emerging discussion of social support groups, individuals seeking help or social support, especially among the chronically ill, have gravitated toward virtual worlds. A study by Norris (2009) found more than 152 healthcare support groups in Second Life including a number of mental health support groups such as Support for Healing, Positive Mental Health, and Depression Support Group; the Transgender Resource Center that provided support for gender identity issues; and Wheelies, a support space for individuals with disabilities. The groups had a total of approximately 10,000 members combined.

Norris found that niche communities were able to flourish in this Second Life space. He explained, "For a healthcare support group, this is a boon, in that it allows those with rare diseases to interact with each other. However, in a larger sense, it also allows people with unique approaches to their issues to interact with each other" (p. 6). The study looked at other platforms apart from Second Life such as IMVU, There (dead in XXXX (nope, it's back!)) and Kaneva, but found that Second Life by far offered the largest number of participants and was the most graphically advanced of the platforms. For instance, "IMVU uses more of the simple 'chat' type groups" (p. 8).

Similar to Norris (2009), Beard, Wilson, Morra and Keelen searched for health-related sites but remained exclusive to the Second Life platform. They found the most common type of use of the social virtual world for health purpose was for "patient education or to increase awareness about health issues" (p. 2) while the second most popular use was for support.

## *4.2 Strengths and Weaknesses of Virtual Worlds for Health-Related Social Support Groups*

Most of the advantages and disadvantages of online support also apply to virtual worlds. In addition to those already mentioned, as a result of a perceived absence of physical and resource limitations or social prejudice, participants may experience a heightened sense of autonomy (Davis, 2011). Also, family members of someone in need of social support can participate in these online communities, which, in turn help them better understand the situation. These features, as supported in Second Life, along with providing a source of "instant pleasures, as liberation from social norms, as a tool for self-expression, and as exploration and novelty" (Partala, 2011, p. 787) resulted in positive emotions, including joy and relaxation among those studied in the virtual world. These emotions can be manipulated in virtual environments by exposing the user to different in-world events.

Similarly, for people with disabilities, engaging with technology can be empowering. In the review of healthcare support groups in Second Life, Norris (2009) found 25 % of those groups belonged to the disabilities category. In their study one such group of adults with disabilities in Second Life, Zielke, Roome, and Krueger (2009) reference "e-empowerment," a concept that posits that the Internet is a powerful avenue to reframe identity, increase self-efficacy and skills, social compensation, and high self-disclosure. They found that taking part in virtual realities allows participants to experience control over their environment and success in activities that are usually inaccessible to them. These authors conclude that as a result of participation in a virtual environment, participants with severe intellectual and physical disabilities could be attracted to more active and physically demanding leisure activities in real life. Additionally, they found that support groups in general base themselves on the premise that people who share similar difficulties, misery, pain, disease condition, or distress may understand each other better and offer mutual emotional and pragmatic support. Their research suggests that online support groups are therefore successful because of, among other factors, the expression and connecting to emotions, and the effects of interpersonal relationships and social processes (Zielke et al., 2009).

These processes can be replicated in virtual worlds because they reflect the persistent social and material world (Preece & Maloney-Krichmar, 2003). Social interaction occurs through both verbal and non-verbal forms that are consistent with real-life communication including speech, writing, and body language. In this sense, the nonverbal cues include avatar posturing, appearance, movement, proximity to other avatars, and sound effects are typically enacted via and “animation override” or menu and as such are rhetorical performance of reality (Verhulsdonck & Morie, 2009); the verbal forms include both text chat and voice chat (Preece & Maloney-Krichmar, 2003; Wang & Hsu, 2009). To further replicate reality, the technology is designed “to make sounds become louder as the avatar moves closer to the source” (Beard, Wilson, Morra and Keelan, p. 3).

The role of anonymity in virtual worlds, especially among patient communities, appears consistently as a benefit in the research. Anonymity is discussed in a study of relationships in Second Life that concluded “study participants consistently cited anonymity via a virtual persona and the sense that virtual actions did not share the same depth of potential consequence as they would in real life, as a source of confidence to explore their sense of self and others in a perceived “safe” environment” (Davis, 2011). Bargh and McKenna (2004) likewise found the “relative anonymity aspect encourages self-expression, and the relative absence of physical and nonverbal interaction cues (e.g. attractiveness) facilitates the formation of relationships on other, deeper bases such as shared values and beliefs” (p. 586). Beard, Wilson, Morra, and Keelan (2009) also found that one of the most important attributes of the environment resulting in these outcomes were, like other online support communities, “both anonymity and interactivity” (p. 12). They wrote, “They [participants] can consult with experts and other individuals with shared experiences, either privately or publicly in a group setting. Even when engaged in public discourse, there is still an element of privacy that does not exist in real-world interactions” (p. 13).

Although the advantages of online support communities are well documented, disadvantages identified in the literature include lack of access to Internet or technology, concerns about addiction, and growing questions about privacy and confidentiality (White & Dorman, 2001).

## *4.3 Virtual Identity and Relationship Formation*

As a result of the attributes unique to virtual worlds, there are possibilities for creative self-expression that may not exist in participants’ physical lives. Consequently, studies show that Second Life has offline behavior implications, which in turn has implications for health care. Specifically, Beard et al. (2009) found that "When people practice health behaviors in a virtual world, they are more apt to perform them in the real world" and suggest that, "The number of health sites within SL indicates a need for this type of interaction in health care" (p. 11).

Relationships, which are fundamental to successful social support groups, also play a crucial role for the user in Second Life. In this virtual world it is "easier and faster to build deep and meaningful relationships with other people—It is easier to find people with similar interests, life situations, or personality traits, and people can form relationships independent of real life barriers of race, gender, income, age, social status, or looks" (Partala, 2011, p. 793).

Partala found that some people experience higher self-esteem in Second Life than in the physical world, and that SL develops that self-esteem, which, in some cases carries out to their physical world behavior. Furthermore, Partala says it is typical for Second Life users to use the platform to gain positive psychological effects. Therapeutic uses of the platform maybe motivated by "real-life depression, stress, a handicap, issues related to physical appearance, or a given personality trait," (p. 795) among other things. This kind of self-therapy can be very successful and could also lead to positive long-term personal development.

## *4.4 Technological Obstacles and Challenges*

Although the benefits are numerous, among potential challenges for participating in SL in general, is that participants could get lost in the virtual world. Wang and Hsu (2009) overcame this by providing study participants with a notecard (a form of email within the virtual world) that included a landmark to the group, or URL (in Second Life called a SLurL) that provides an instant "teleport" or link to the virtual location. This process brings individuals in the virtual world together fast and efficiently. Wang and Hsu also found that learning how to use SL was a difficult task because the basic classes provided by Linden Labs, the creators of Second Life, and others are relatively short, and the information could be overwhelming and confusing. Learning the key skills, according to Wang and Hsu, requires regular practice on participants' own time.

In discussion of challenges of functioning in the virtual world, Wang and Hsu also addressed the important role of facilitation in online support groups. In-person face-to-face groups have revealed that efficient facilitation includes directing communication amongst members, reminding of group tasks at hand, providing a structure to the group, and resolving potential conflicts. Facilitating group discussions in Second Life require particular skills that must be tailored and shaped to account for this media. "Whereas in the in-person environment the facilitators' physical presence conveys a good deal through body language, the virtual environment... necessitates revision of communication so that a charismatic ambience may still be maintained in inspiring participation. Keys in virtual communication thus rely more heavily on avatar body appearance, some emoting of animations, and vocal inflections of the facilitator" (Wang & Hsu, 2009, p. 4).

Other challenges or barriers for those seeking social support in the virtual world are technical functions. For instance, there may be a delay when the avatar moves to a new location, because all the specifications for the environment must be downloaded from the server (Bainbridge, 2007). Additionally, Second Life has what may be considered high-end hardware requirements. Users might need to upgrade their computer equipment such as improved graphics card or internet speed in order to smoothly run Second Life without delayed functioning or experiencing rough graphic effects. Wang and Hsu reported that many organizations and schools block the use of Second Life because it occupies the network bandwidth (Wang & Hsu, 2009).

## 5 Case Study: Parkinson's Support Group in Second Life

With an understanding of the potential benefits of support groups in the 3D immersive virtual world, this case study is currently investigating the effects of an online support group for individuals who have been diagnosed with Parkinson's disease. According to the National Institutes of Health, more than 500,000 people in the US suffer from Parkinson's disease (PD), with "50,000 new cases reported annually" (NIH, 2014). An online search of support groups for Parkinson's identified more than 4 million results, most of which are face-to-face meetings or online forums.

Evidence of effective health-related activities and healthcare support groups in virtual worlds specifically is relatively new, with the earliest research emerging in 2008 as virtual reality became more accessible and user traffic became more wide spread (Beard et al., 2009; Krebs et al., 2009; Norris, 2009; Toro-Troconis et al., 2008). The mediated effects found in the literature discussed, including anonymity, access to peers and the sense of presence in these environments (Heeter, 1992; Lee, 2004) as well as the social capital formed in the virtual world (Bargh & McKenna 2004; Davis, 2011; Parks & Roberts, 1998; Roberts et al. 1996), warrant further exploration for healthcare community development and outreach with tremendous potential value in patient support and recovery.

Also revealed in the literature is the importance of access regardless of time, geography or access to caregiving. Such is especially the case with individuals who suffer from disabilities or debilitating conditions such as Parkinson's disease when mobility is further diminished. This case example explored the use of support meetings and functioning in a virtual community to determine potential benefit.

## *5.1 Ethnographic Approach and Theoretical Underpinnings*

Because this research is exploring the evolution of a new form of community about which very little is currently known, this ethnographic study employed participant observation in two stages: First, the researcher attended both the public social events of the "Creations for Parkinson's" group in the virtual world, Second Life. Second, the researcher attended the organizations' weekly support group as an observer. Following approximately 6 months of engaging in the community, clear themes emerged including the value placed on connection to others with PD, being able to express their feelings openly, and learning about living with PD from others.

From a theoretical perspective, media effects and uses and gratifications theory guided this study. McLuhan suggested nearly half a century ago that media was an "extension of man" (1964). His reference of media at that point was limited to traditional forms of media such as newspaper, television and radio. Media today has evolved to the immersive form of 3-D online virtual worlds where people are interacting with the screen, almost as though they've jumped right into the environment, rather than experiencing it as passive observers. If, in fact, individuals whose physical function is diminished as a result of Parkinson's disease are able to continue to live what they perceive to be a "normal" life similar to the one they had prior to their illness, is this not perhaps the most literal definition of media as an extension of man?

Blumler and Katz's uses and gratifications theory (1974) as it has been adapted to Internet uses and gratifications (Song, Larose, Eastin, & Lin, 2004) assumes the user takes an active role in their personal choice of media consumption, based on what they hope to gain from that consumption such as information, entertainment or social gain. This research may further our concept of uses and gratifications when the medium provides basic human need such as social connection or the ability to function in a community where an individual's physical world no longer allows or is significantly limited.

### 5.2 Preliminary Results

Preliminary findings have laid the foundation from which to launch a long-term study on the effects of avatar performance on individuals diagnosed with Parkinson's disease. Similar to the results of Green-Hamann, Eichhorn and Sherblom's (2011) study of support groups in Second Life, anecdotal evidence from individuals participating in a PD support group suggests that as a result of agency, or the *sense* of being physically present in this environment, and by engaging with other individuals in real time that they have experienced improved mobility and/or reduced symptoms of the disease, including depression, in their physical lives. Also of interest, one study participant reports increased mobility and reduced symptoms of her Parkinson's disease since she began watching "herself" (her avatar) engage in physical activities such as dance and tai chi in the virtual environment.

## 6 Conclusion

The literature to date that explores social support in immersive 3-D virtual environments such as Second Life suggests there are tremendous opportunities, especially for individuals who may be socially or physically isolated or who may prefer support in the "safety" of the anonymity that avatar performance provides. Yet, challenges remain. Still, due to the rapidly changing healthcare field, combined with increased access to high-speed internet and technologies, these groups show promise.

As Turner, Grube and Meyers suggested in 2001, online technology was evolving at a pace where access was less an issue while rising healthcare costs were more an issue. They concluded, "Continued study of the development of hyperpersonal communication within a variety of mediated contexts will give us further understanding of how supportive relationships can develop" (p. 249). If indeed they are strong, they could provide a powerful resource for those in need.

As cost and access to healthcare and social support is already challenging for millions of individuals around the globe, access to support online is becoming more mainstream as seen in the growth in telemedicine. Already there are a number of groups and organizations that provide online support, especially in the field of mental health and a growing number of healthcare researchers that are exploring these spaces for both physical and emotional therapeutic support. This trend provides tremendous opportunity, both for individuals whose lives are limited by chronic illness or disability and for organizations and care providers who can provide support in virtual worlds. Implications reveal important questions about using highly engaging immersive social media with a vulnerable population. As technology continues to evolve, especially in the healthcare arena, it will be increasingly important to understand long-term implications that offer benefit while remaining cognizant of the risks.

## References

Bainbridge, W. S. (2007). The scientific research potential of virtual worlds. *Science, 317*, 472.

Bargh, J., & McKenna, K. (2004). The internet and social life. *Annual Review of Psychology, 55*, 573–590.

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

Blumler, J. G., & Katz, E. (1974). *The uses of mass communications: Current perspectives on gratifications research*. Beverly Hills, CA: Sage.

Davis, D. (2011). *Engaging the disengaged via performance in online virtual worlds*. Selected Papers of Internet Research. Association of Internet Research. Retrieved from http://spir.aoir.org/papers/davis.pdf

Ellison, N. B., Steinfield, C., & Lampe, C. (2007). The benefits of Facebook "friends:" Social capital and college students' use of online social network sites. *Journal of Computer-Mediated Communication, 12*(4), Article 1.

Green-Hamann, S., Campbell Eichhorn, K., & Sherblom, J. C. (2011). An exploration of why people participate in Second Life social support groups. *Journal of Computer-Mediated Communication, 16*(4), 465–491.

Haythornthwaite, C., & Kendall, L. (2010). Internet and community. *American Behavioral Scientist, 53*(8), 1083–1094. doi:10.1177/0002764209356242.

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence, Teleoperators and Virtual Environments, 1*, 262–271.

Heim, M. (1991). The erotic ontology of cyberspace. In M. Benedikt (Ed.), *Cyberspace: First steps* (pp. 59–80). Cambridge, MA: MIT Press.

Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukopadhyay, T., & Scherlis, W. (1998). Internet paradox: A social technology that reduces social involvement and psychological well-being? *American Psychologist, 53*, 1017–1031.

Krebs, P., Burkhalter, J., Lewis, S., Hendrickson, T., Chiu, O., Fearn, P., et al. (2009). Development of a virtual reality coping skills game to prevent post-hospitalization smoking relapse in tobacco dependent cancer patients. *Journal of Virtual Worlds Research, 2*(2), 4–12.

Lee, K. M. (2004). Presence, explicated. *Communication Theory, 14*(1), 27–50.

McLuhan, M. (1964). *Understanding media: The extensions of man*. New York, NY: McGraw-Hill.

National Institutes of Health (NIH). (2014). *Parkinson's disease backgrounder*. Retrieved June 22, 2014, from http://www.ninds.nih.gov/disorders/parkinsons_disease/parkinsons_disease_backgrounder.htm

Nie, N. H., & Erbring, L. (2000). *Internet and society*. Stanford Institute for the Quantitative Study of Society.

Norris, J. (2009). The growth and direction of healthcare support groups in virtual worlds. *Journal of Virtual Worlds Research, 2*(2), 3–20.

Parks, M., & Roberts, L. (1998). Making Moosic: The development of personal relationships on line and a comparison to their off-line counterparts. *Journal of Social and Personal Relationships, 15*(4), 517–537.

Partala, T. (2011). Psychological needs and virtual worlds: Case Second Life. *International Journal of Human-Computer Studies, 69*, 787–800.

Preece, J. (2000). *Online communities: Designing usability and supporting sociability*. New York: Wiley.

Preece, J., & Maloney-Krichmar, D. (2003). Online communities. In J. Jacko & A. Sears (Eds.), *Handbook of human-computer interaction* (pp. 596–620). Mahwah, NJ: Lawrence Erlbaum.

Putnam, R. D. (2000). *Bowling alone*. New York, NY: Simon & Schuster.

Ren, Y., Harper, F. M., Drenner, S., Terveen, L., Kiesler, S., Riedl, J., et al. (2012). Building member attachment in online communities: Applying theories of group identity and interpersonal bonds. *MIS Quarterly, 36*(3), 841–864.

Roberts, L. D., Smith, L. M., & Pollock, C. (1996). *Social interaction in MOOs: Constraints and opportunities of a text-based virtual environment for interpersonal communication*. Abstract retrieved May 27, 2004, from http://wwwmcc.murdoch.edu.au/ReadingRoom/VID/VIDpap.html

Schaefer, C., Coyne, J., & Lazarus, R. (1981). The health-related functions of social support. *Journal of Behavioral Medicine, 4*(4), 381–406.

Song, I., Larose, R., Eastin, M., & Lin, C. (2004). Internet gratifications and internet addiction: On the uses and abuses of new media. *CyberPsychology & Behavior, 7*(4), 384–394.

Symister, P., & Friend, R. (2003). The influence of social support and problematic support on optimism and depression in chronic illness: A prospective study evaluating self-esteem as mediator. *Health Psychology, 22*(2), 123–129. doi:10.1037/0278-6133.22.2.123.

Toro-Troconis, M., Mellström, U., Partridge, M., Meera, K., Barrett, M., & Higham, J. (2008). Designing game-based learning activities for virtual patients in Second Life. *Journal of CyberTherapy & Rehabilitation, 1*(3), 225–238.

Turkle, S. (1984). *The second self*. New York, NY: Simon & Schuster.

Turkle, S. (1996). Virtuality and its discontents: Searching for community in cyberspace. *The American Prospect, 24*, 50–57.

Turkle, S. (2010). *Alone together: Why we expect more from technology and less from each other*. New York, NY: Basic Books.

Turkle, S. (2011). *Life on the screen*. New York: Simon and Schuster.

Turner, J., Grube, J., & Meyers, J. (2001). Developing an optimal match within online communities: An exploration of CMC support communities and traditional support. *Journal of Communication, 51*(2), 231–251.

Verhulsdonck, G., & Morie, J. (2009). Virtual Chironomia: Developing standards for non-verbal communication in virtual worlds. *Journal for Virtual Worlds Research,* North America. Retrieved October 27, 2013, from http://jvwr-ojs-utexas.tdl.org/jvwr/index.php/jvwr/article/view/657

Wang, S., & Hsu, H. (2009). Using the ADDIE model to design Second Life activities for online learners. *TechTrends: Linking Research and Practice to Improve Learning, 53*(8), 76–82.

Warren, R. (1978). *Community in America*. Chicago, IL: Rand McNally.

White, M., & Dorman, S. (2001). Receiving social support online: Implications for health education. *Health Education Research, 16*(6), 693–707.

Zielke, M., Roome, T., & Krueger, A. (2009). A composite adult learning model for virtual world residents with disabilities: A case study of the Virtual Ability Second Life Island. *Journal of Virtual Worlds Research, 2*(1), 3–21.

# Virtual Fashion as an Industry: Making the World Look Better One Avatar at a Time

**Phylis Johnson**

## 1 Introduction

"Girls who love fashion" might seem a stereotypical statement; nonetheless it is also reflective of the growing market for PC games catering to the interests of female youth. Listed under a web site of a similar name, one soon discovers a multitude of online games at http://www.gamesforgirlswholovefashion.com. The directory includes *OurWorld* ("The best online fashion & dress up game"), *Jojo's Fashion Show World* ("Are you ready to take on the world of fashion?"), *Goodgame Fashion* ("Open up your own fashion shop"), *IMVU* ("Create yourself"), and others. Founded in 2004, *IMVU* (2014) reported 50 million registered members in its first decade, along with 3 million active users, and a marketplace of more than 6 million "virtual goods," according its web site. Various fashion games, such as *Hip Chicas*, *Miss Bimbo*, *Spark City*, *Disney City Girl*, *Coco Girl*, *Innerstar University*, and *Mall World* are classified as simulations and/or virtual worlds, with the majority of them surfacing in 2012 and 2013, targeted to tweens (*Girls Gamsey*, 2009; *Virtual Worlds for Tweens*, 2014).

Fashion is not always child play in the virtual arena. *The Sims* series, with its first release in 2000, attracts players 13 years and older. It is not a virtual world in its fullest sense, but it did pave the way for other immersive fashion experiences like *Second Life*. The game is best described as a simulation of life, with objectives and boundaries shifting over the years through the upgrades, add-on packages, and versions. There is no real mission, other than for members to engage in life-like activities—work, play, establishing relationships, raising families, and creative art and play that has become an offshoot of the game. As the one of the most successful video games in history, if based on sales alone, more than 20 million copies of the

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**Fig. 1** Avatar customization has become increasingly popular (© 2012, P. Johnson)

first two editions have sold internationally. *The Sims* might be considered the forerunner to *Second Life*, with the latter affording more control and creativity to its members and attracting the older middle-aged players to make the leap. In fact, some of *The Sims* members moved onto *Second Life* after its debut in 2003. *The Sims 3* offers more tools for fashion customization than the older versions, and *The Sims 4's* late 2014 release focuses on advances in overall avatar appearance, animations and clothing styles. Whereas *Second Life* is a virtual world built on the creative contributions of members, *The Sims* (2014) provides packaged experiences with much less flexibility for users. *The Sims*' members and those of *Second Life* have both established a number of online communities that feature apparel as well as fashion tips, blogs and media (Fig. 1).

As a creator-inspired platform, *Second Life* advanced quickly in both simulating real life activities as well as challenging its boundaries and rules. That is why this chapter focuses on its rise among virtual fashionista, while contextualizing its evolution across various platforms. As time progressed and *Second Life* matured, creators became more sophisticated in their designs and the fashion industry flourished there as it has gradually for *The Sims.* Avatar clothes for children to adults are available to match every role play occasion. *Second Life* is basically an adult game, with some exceptions for supervised instructional activities targeted toward preteens, 13–15 years old. In *Second Life*, participants must be at least 16 years old, with significant restrictions for those under 18 years old; another version that allowed for youth (13–17) to join the Teen Grid was discontinued in 2010. The virtual game *OurWorld* has been promoted as one of the top games for girls interested in fashion. Launched in 2008, "Not only can you dress your avatar up in a huge range of fashionable clothes to choose from, but you can customize and change your avatars . . ..from a blond girl to an Indian Muslim girl, quite a different look!" (*Games for girls*, 2014). Not nearly as sophisticated as *The Sims* and *Second Life*, it does call attention to a growing need and interest in attending to an international market and a diverse population of members. The *Second Life* fashion


**Fig. 2** *Second Life* fashionista strive for perfection (© 2013, Belinda Barnes. Used with permission)


**Fig. 3** *Second Life* fashion accessories (© 2013, Belinda Barnes. Used with permission)

industry has capitalized on the ability to customize one's avatar, by top designers both men and women with an eye and skill for texture, form and graphic design (Fig. 2).

It can be divided into various categories: skin, shape, hair, and clothing. That is only the start. Some designers specialize in feet and shoes. Others might design eyes, finger nails, jewelry and other accessories (Fig. 3).

The list is limited to one's imagination, for there are plenty of talented designers. Looking good as an avatar can mean achieving social success in a virtual world and even landing a modeling job and a magazine cover. With the 2007 launch of

*OpenSim*, a *Second Life* derivative that promised greater freedom and control over content and intellectual rights, some designers made the jump, hoping to either set up virtual world franchises or to start anew in what was perceived as a step forward by some members. The *OpenSim* fashion scene remains in its infancy; its membership represents a fraction of *Second Life*'s more than 37 million registrants (45,000 median active users) compared to *OpenSim's* 350,000 (21,000 active users) (Voyager, 2013, 2014b).

## 2 Fashion Economies of Virtual Worlds

Daniel Terdiman's *The Entrepreneur's Guide to Second Life: Making Money in the Metaverse* (2007) touched upon the virtual fashion industry, which had hardly reached its heyday when the book was published. Books that address *Second Life* fashion and/or virtual identity date back to the early years of *Second Life*—Rebecca Tapley's *Designing Your Second Life* (2007), Pascal Volino's (2000) *Virtual Clothing*, Peter Ludlow and Mark Wallace's (2007) *The Second Life Herald: The Virtual Tabloid that Witnessed the Dawn of the Metaverse*, and Astrid Ensslin and Eben Muse's *Creating Second Lives: Community, Identity and Spatiality as Constructions of the Virtual* (2011). Collectively, some of these books begin to tell the story of *Second Life's* rise in virtual couture. Shenlei E. Winkler (2009), founder of the Fashion Research Institute, Inc., and author of *Designing Dreams: Best Practices for the Art & Business of Avatar Apparel Design & Development,* offers examples of couture customization. Winkler has 30 years of fashion design experience and an additional decade of technical marketing experience. On her web site, she notes that her work has accounted for millions in sales and an Intel Corporation collaboration "to continue research into the use of virtual worlds as an accessible 3D medium for creative industries" (Winkler, 2012). Within *Second Life*, she is known for her project "Carriage Trade," a horse lover inspired line of fashion for avatar horses and riders. Worthy of mention, she has a growing body of research based on her own marketing, licensing and design experiences in virtual worlds.

Elaine Polvinen (2008), in a blog post "Virtual Fashion—What is it?," looks to Winkler for a definition of virtual fashion, apart from acknowledgement of the nearly $2 trillion fashion industry as incentive; it is a blurring of lines between real and virtual with the emergence of 3D digital formats that makes it difficult to pinpoint conceptually. Consider that was more than 5 years ago; since then, 3D printers have further revolutionized the couture market, and confounded coming to terms with a definitive understanding that distinguishes virtual fashion from real and simulated worlds like *Second Life*. To complicate the matter, also consider, as Polvinen has pointed out, "Some real life fashion designers like Nyla from the House of Nyla design create one of a kind real world fashions and replicate them for virtual sales in a virtual world like *Second Life*." Along that line, Winkler has been determined to find real ways to "cut. . .time to market, slash its development costs. . .and enhance. . .profitability and revenue opportunities" (Polvinen, 2008).

With that said, Winkler sees her Fashion Research Institute as a means to "insulate" creators from labor intensive market and technology concerns, so that one might focus on design using virtual worlds as a platform.

Further evidence that the fashion industry has embraced virtually its creation of real world fashion is the success of start-ups experimenting with 3D printed couture and the rise of wearable technology (Rodat-Savla, 2014). Reports vary on the fashion economy in virtual worlds, with estimates from one to two billion dollars (Brooks, 2009; La Ferla, 2009). In 2010, reports indicated among the nearly one million *Second Life* residents, consumer purchases equated to more than US$500 million (*Rosenwald*, 2010). A good portion of *Second Life* economy centers on the fashionista culture, from runaway fashion shows to glossy color ads and feature stories in magazines, to virtual/streamed television shows, to a whole network of blogs and social media. Most outfits range a few pennies to a few dollars, while some outfits are priced higher for formal and special occasions; then add shoes and other accessories, and the costs accumulate fairly quickly. Gwen Chadwick (2010) reported women accounted for 40 % of the sales in virtual clothing and accessories in *Second Life*; women over 40 years-old also represented a significant portion of active *Second Life* users in 2009. Those numbers likely have increased since then, but certainly they represent a substantial market for the virtual fashion industry. Estimates from 5 years ago indicated sustained growth in *Second Life*'s virtual economy—a large portion of that is appearance (i.e., skins, shapes, clothing, and accessories) for ages 25-to-50 years old, according to La Ferla (2009). Over the years, a simple web search reveals the virtual fashion market spans from avatar costumes sporting medieval designs for *World of Warcraft* players, to a wide array of fashion associated with *Entropia Universe, The Sims* (series), and *Second Life*.

In the case of the latter, *Second Life* designers have progressively sought ways to craft virtual outfits that might be marketable in real life, and vice versa. A few companies like the short-lived virtual presence of American Apparel have experimented with versions of their real product within *Second Life*. Others represented have included Adidas and Reebok (Carella, 2007). The reason being explained best by Marketing Executive David Lauren of Polo Ralph Lauren who stated that the trend towards virtual fashion arose, in part, from "prohibitive" travel costs for press and buyers (Betts, 2009). For some cutting edge designers, real life events like New York Fashion Week might work as well as, or perhaps better, in the future virtually. The fashion industry within *Second Life* has sponsored major events aligned with in-world music performers and not-for-profit organizations. Some long-standing *Second Life* companies, like Redgrave, have noted plans for or initiated *Second Life*/real life product lines. Others like Spanish fashion label El Ganso have opted to test products and promote virtually, "rethinking the traditional fashion show" (Betts, 2009). Other examples include British designer Alexander McQueen's "live-streaming [of] his Paris show on his website. . .Louis Vuitton live-streamed its show on Facebook. . .. Ideally, consumers who watch a show online would then be able to click on a product they see and buy it immediately" (Betts, 2009) (Fig. 4).

**Fig. 4** Virtual glamour (© 2014, Belinda Barnes. Used with permission)

## 3 Rise of the Virtual Fashion Empire

High glossy magazines, virtual filmmaking, and radio and television advertising along with countless hi-brow theatrical fashion shows, have seduced men and women to style their avatars, for what one might call the ultimate form of role play. This mindset—and hard work—among designers and affiliated agents has increasingly enticed real life fashion moguls to engage in some serious "play" in the virtual arena. The currency exchanged is real. *Second Life* has a vibrant fashion scene, with virtual residents participating at varying levels with traditional and alternative appearances. Appearance may mimic real life. Initially the avatars were limited to a handful of choices. Within a few years, skins, shapes and clothing styles expanded. By 2007, the fashion industry had exploded within *Second Life*. In 2010, sessions surrounding fashion, from tips on virtual modeling to marketing in *Second Life* and real life, headlined at the *Second Life* Community Convention.

In the case of *Second Life*, just like everything else, the creators contribute to a community that simulates real life or helps create an alternate scenario, left to one's imagination. One of the leaders of the fashion industry has been *Best of SL Magazine* (BOSL) founder and then CEO Frolic Mills (Fig. 5)., who after 5 years recently sold his enterprise. The Venezuelan entrepreneur helped to propel the high fashion district to new heights, along with other fashion entrepreneurs who had a growing interest in this unfolding world. He launched the annual Miss Virtual World and Mr. Virtual World, which brought notoriety to the virtual fashion world with thousands viewing the ceremony online in countries around the world. The magazine itself reported on the fashion scene from inside *Second Life*, and it revolutionized how the fashion industry would be perceived (Johnson, 2010b, 2013) (Fig. 6).

**Fig. 5** Frolic Mills, former CEO of BOSL (© 2013, P. Johnson)

**Fig. 6** CottonCandy Teardrop, Ms. Virtual Australia 2014 (© 2013, P. Johnson)

Suddenly, the *Second Life* fashion scene exploded with full-page fashion advertisements in virtual magazines, newspapers, radio, television and machinima (via animated filming used to capture in-world/game footage). Top magazines aside from *Best of SL Magazine*, included *Second Style*, *BeStyle: The Best of Italian Style*, *Avenue Magazine*, *Essence*, and *Vain Inc*. A virtual replica of Rodeo Drive, and comparable high-end districts of Tokyo, London, Paris, and other fashion meccas, appeared. Just like in real life, virtual billboards flew above business districts and malls. Television shows featured models, publishers, night clubs and celebrity designers, all coming together to showcase fashionista of the virtual kind. Virtual fashion provided eye candy for media, attracting the attention of real and virtual audiences. *Fabulous Fashion* with host Angie Mornington made its debut in 2008 on *Second Life* Cable Network (Johnson, 2010b); the opening shot is the African-American hostess walking through high-end fashion districts. The long-running series has showcased internationally renowned fashion publishers, models, and celebrities, complete with fashion challenges. At the height of the fashion machinima movement, professional machinima filmmaker Lowe Runo was contracted to produce a series of fashion vignettes, along with Prism Fashion designer Journey McLaglen, for *Fashion Week*. Machinima artistically captured runway shows featuring leading fashionista; theatrical performances ranged from fantasy to exotic interpretations of brands (Johnson, 2010a). Since then, fashion shows, in all their forms, live and recorded, have become foundational to the virtual world. In 2010, Metaverse Television had broadcast the third annual Miss Tropic Hawaiian Pageant in Oahu, Hawaii (the *Second Life* version, that is). Proceeds for many of these shows go towards non-profit organizations, with Relay for Life being one of the most prominent recipients (Voyager, 2014a). Themed shows, introducing new fashion lines, involved teams of designers and organizers that emulated Hollywood, Bollywood, Broadway and a plethora of cutting-edge theatrical production styles, but in the virtual world (i.e., Cortes, 2010; *Digital Image*, 2007; Scofield, 2010).

Designers and the stores that carry their brands have become part of the communities in which their patrons reside, virtually. The *Second Life* fashion legacy has matured, but its fervor continues today. A huge wedding fashion business inspires romance; fantasy fairs inspire imagination, and 'dreams come true' becomes an underlying theme of many productions. *Second Life* designers have achieved numerous brands that cater to the virtual market, in extraordinarily ways that engage consumers' attention and purses. Loyal patrons await new releases with great anticipation, lining up outside virtual stores or packing the stores en masse. The virtual strength of the fashion world are the content creators, who often lead the way, rather than merely duplicate what already exists in one's real life. True, outfits that reflect daily life enhance the comfort level of some virtual patrons. Yet, *Second Life* has continually attracted designers willing to challenge daily norms, being curious about what the future might look like from a fashion perspective. At one point, former *Second Life* CEO Mark Kingdon posited, "'the next natural wave' is a digital shopping experience…the attributes that we see today in *Second Life*" (Naone, 2008).

## 4 Avatars Reflecting World Diversity

The virtual fashion industry has gradually improved its offerings with respect to representation across gender, race and ethnicity. Critics and observers have had a long-standing debate on issues of media diversity and representation as clearly denoted by a number of communication and technology scholars (Bosah, 1998; Everett, 2011; Johnson, 2014; Leung, 2005; Nakamura & Chow-White, 2011). Likewise, diversity in terms of skin, appearance and clothing was slow to evolve within *Second Life*. In recent years, a virtual public outcry for better skin selections and body representation has provoked designers to address the needs and wants of consumers (i.e., Beliveau, 2011; Coachman, 2010; Delvalle, 2011). The market for white European avatars, while still the norm in virtual culture, is being re-conceptualized with greater consideration toward global membership and representation (Figs. 7 and 8).

One *Second Life* forum garnered the attention of more than 650 views within 2 days, with several participants (e.g., Magic, 2011; Ohna, 2011; Vuissent, 2011) pointing out the need for "non-white skins," namely Asian, Latino and Black, as well as the need of mature and fuller shapes for older residents. One noted her desire to just see more ordinary 'avatar' people. Others like Max Burns (2009), online curator of the blog *Pixels and Polic*y, conducted his own survey of race and gender, on separate occasions, pointing out that females represented in Second Life were primarily concerned with their bust size, the idea that "female avatars reflect real-world gender expectations," and a number of women were dismayed and or conflicted with this virtual representation. Another study from Nottingham Trent University was cited by Burns, (2009), stating that "up to 70 % of women" compared to a little more than half of all men were likely to create an avatar of the opposite gender. Identity construction in virtual worlds is a mixed bag, with challenges from Lynda Boudreault and Joseph Moser (2012) that *Second Life* did indeed provide a positive environment. They propose that "real-life markers" can be "mitigated and potentially neutralized," and expressive opportunities emerge in such spaces. *Second Life* has grown considerably diverse, with a plethora of retail stores featuring skins, shapes and clothing reflective of cultures from around the world (e.g., India, China, Japan, Brazil, Portugal, Mexico, South Korea, and Africa), far more representative of membership in recent years (Figs. 9, 10, and 11).

Other diversity comes in the way of fantasy fashion, where science fiction interests and ideals influence wardrobe and overall appearance, from aliens to creatures to anything anyone might imagine. Some choose to have avatars dress nostalgically, from particular eras reflective of Medieval and Victorian times to Berlin, Chicago, or Paris in the 1920s, 1930s, and 1940s, to Asian and European influences of various periods. The Netherlands' Jo Yardley (2014) of The Berlin Project is one of the most notable role play designers in *Second Life*, known for her historically accurate settings and clothing. Her blog "The Adventures of a Time Traveler" keeps up with trends and issues in content creation. The burgeoning couture or fashion culture in *Second Life* is what distinguishes it from other online


**Fig. 7** Skin matters in *Second Life* (© 2012, Belinda Barnes. Used with permission)

**Fig. 8** 'Authors' Dr. Dame Dhyana Ziegler and "Pip" William Guest as themselves in *Second Life*, celebrating the publication of *Midnight Train From Georgia: A Pip's Journey* November 2014 with a Motown tribute show and book signing

**Fig. 9** Diversity in *Second Life* © 2011–2012, Belinda Barnes (Used with permission)

**Fig. 10** Science Fiction as Virtual Expression © 2011–2012, Kara Trapdoor (Used with permission)

platforms and virtual worlds. There is also the idea that one can live vicariously though their avatar, experiencing near perfection from hair to toe nails, in attempting to eliminate perceived human flaws in a virtual society. That is not the intent of all *Second Life* designers. Alas, at any given moment, one might be dressed as an executive in a tailored suit, and the next as a vampire immersed in a gothic subculture. That same avatar might be a model on a fashion runway that weekend. All the elements to meet one's fashion wants for every imaginable role in *Second Life* can be pursued, at a price, with technology increasingly allowing for an impeccably designed and outfitted avatar.

**Fig. 11** Fantasy in *Second Life* © 2011–2012, Belinda Barnes (Used with permission)

## 5 Avatar as Virtual Doll

Flickr.com, an online photography social media site, was primarily established for those sharing real-life images, yet there is a strong presence of *Second Life* members. Numerous accounts under the names of persons' avatars indicate how seriously invested members are into their appearances. A considerable among of attention is directed toward fashionista. Many choose to display their avatars as beautiful icons, composed and strikingly realistic; for examples, see the Flickr site of top *Second Life* fashion retailer Mimi Juneau (2014) (of Mimi's Choice) featuring top models and fashions, as well as her social network). Such enterprise is more than homage to a Barbie subculture; that would be too simple of an explanation. There is much thought put into the making of the avatar, as actualized by their creators. In real life, one might spend years of cosmetic/plastic surgery to attain this idealized (yet often stark) view of female perfection. The degree of diversity, however, of one's appearance is rooted in the owner's intentions. Some avatars appear to have warm vibrant personalities. Others are constructed as caricatures, puppets, or something nearly but not quite human (Fig. 12).

Two renowned *Second Life* artists Alles Klaar and Kynne Llewellyn, have created amazing immersive installations and art works themed on dolls. In April 2012, under my avatar name I photographed (and archived) their opening of *The Secret Life of Dolls* at a *Second Life* exhibit at OrCafe (Fitzroy, 2012a). A feature article (under my avatar name Sonicity Fitzroy) was published in *Best of SL Life Magazine*'s May 2012 issue (Fitzroy, 2012b). One readily acknowledges the avatar as a statement of beauty and complexity, struggling between reality and imagination; its juxtaposition amidst non-standard perfection delivers a mixed message of one's place in a virtual world (Fig. 13).


**Fig. 12** Artist Alles Klaar's work at *Secret Life of Dolls* (© 2012, P. Johnson)

**Fig. 13** *Secret Life of Dolls'* Kynne Llewellyn (© 2012, P. Johnson)

The avatar is constructed as a work of art, and captures a unique interpretation of beauty and fashion. Its creators have brought their dolls to virtual life, while simultaneously each being that avatar, as artists within the virtual canvas of *Second Life* and embodied as the other. McLuhan addressed the concept of technology as an extension and elaboration of humanity. Is it not the case of stepping out of one's body, in many instances, to a new space of contemplation and actualization, to build upon notions of personhood and community? For others, it is a matter of improving upon their insecurities or even embracing flaws to accentuate them in novel ways that challenge mainstream notions. The world of fashion in a virtual world can be directly viewed as glorifying (and an extension of) a consumer "self" culture, or alternately it can be deemed the tip of an emergent holographic world order where physicality, in terms of body look and function, becomes technologically changeable, part of a wearable new world order; a HUD (head's up display) so to speak in game lingo. In the virtual fashion scene, a HUD allows the purchaser to choose among many appearance options.

In *Second Life*, and other virtual worlds, avatar fashion has both inspired and been inspired by technology. From the initial primitives (building blocks) came flexible primitives, sculptees (sculptured), and mesh (contoured); all were core to the progressive developments in *Second Life* avatar fashion, with each having its unique benefits, issues and opportunities. In the same way, avatars' shapes allow for customization to the point that consumers can upgrade or replace nearly every extremity, from head to hands to breasts to bottom to feet. Skin and shapes cater to various tastes, those reflecting race, ethnicity, and gender/transgendered as well as in-world body fads. Popular brands such as Lolas and Phat Azz, designed to accent the breasts and behind respectively, have generated unique communities based on similar interests in body modification. Moreover, communities have formed around nekos (feline-inspired), elves, fairies, and Furries, to name only some alternatives. Just as body and skins evolve, the ideal avatar is dependent on personal choice, customization skill level, and what is available from designers. As *Second Life* prepares for the introduction of a 'sister' world in the near future, some bloggers are reviewing what has been learned this decade regarding avatar appearance and customization. This is not merely the case for *Second Life*, as other worlds consider major upgrades (Figs. 14 and 15).

For one, the virtual world has both challenged and reinforced stereotypes; technology does not necessarily guarantee nor promise overcoming them. "Medieval Barbie with 3D Printed Battle Armor," by Scott Grunewald (2014), underscores how countering stereotypes, such as the Barbie ideal, is possible within a game culture. Two, for *Second Life* fashionista, advances in technology has meant considerable retraining for creators, the exit of those not willing to keep up with


**Fig. 14** Furry to Medieval Warrior © 2012–2014, Belinda Barnes (Used with permission)

**Fig. 15** Furry to Medieval Warrior © 2012–2014, Kara Trapdoor (Used with permission)

trends and advances, and the entrance of new entrepreneurs. The fashion industry, in general, outside of the virtual realm, has been challenged in keeping pace with technology. Innovators such as Artist Xuedi Chen's wearable 3D printed mesh have projected political statements, albeit via a sort of fashion philosophy—"a glimpse at the inescapable loss of privacy in our digital connectedness" (Chavez, 2014). In the case of Chen's work, "...the final product combines a flexible 3D printed mesh, structural fabric and reactive display material connected to a mobile app." The result is "the wearer becomes more digitally exposed"—in essence revealing the "naked truth" of our lives (Chavez, 2014).

Fashion exposes one's insecurities, a need to share one's life, and a mutual dependence on material culture (Fig. 16). Similarly fashion designers of *Second Life* and more generally virtual words become conflicted in how they might master rapidly changing technology, consumer demands, and still maintain a sense of personal aesthetic in their content. What is overcome is a lengthy process that separates imagination (as embodied in virtual worlds) from creation and distribution. The gaming world is beginning to realize the potential of 3D printing and Oculus Rift as changing how one plays and lives virtually, and how that interweaves within one's very existence, wishes and dreams. In the 2014 Fashion Conference SOURCING, 3D printing headlined as the theme, with an eye toward revolutionizing the design side of the industry (Molitch-Hou, 2014). As virtual worlds offer opportunity for experimentation and visualization, in all forms from clothing to home design, they will be seen as part of the process of human creation, not isolated as a fad or an extension of virtual societies and gaming culture—but as the bridge, or even the first step in the execution of an idea. Virtual worlds might also provide richer experiences and opportunities for disabled populations to live

**Fig. 16** Facing one's insecurities in a virtual world (© 2012, Belinda Barnes. Used with permission)

fuller lives with technological assistance of various forms, minimizing the digital divide at least physically (Park, 2013; *Virtual Abilities*, 2014). Fashion, or refashioning, of what it means to be human is very much related to questions on the implications of 'being" in a virtual culture, where immersivity connects the human spirit across perceived and arguably artificial boundaries. The avatar, at present, allows entrance into the virtual frontier, and itself becomes part of our "wearable" aesthetic.

## 6 Conclusion

The premise for a virtual world is a mix of simulation, a second chance at the real world, a playful way to live out one's fantasies, jump into dreams, and allow things that one only imagined would come to fruition. All that becomes a factor in one's perception of identity. It is a space where individuals can thrive outside of human constraints to, for instance, experience life as machine, alien, animal or any creature yet unrealized. Sherry Turkle (2012), in *Alone Together: Why We Expect More From Technology,* explains how individuals seek to be themselves or what they believe as an improved self, adding "Technology is seductive when what it offers meets our human vulnerabilities" (p. 1). Such factors lead to wardrobe decisions, where one lives virtually, and are suggestive of personal and collective identities in the acting out of perceived roles. One cannot escape the influence and presence of others. The material culture of virtual appearance, as embodied by the skin, shape, clothing, jewelry and other accessories of choice, contribute to one's identity—

**Fig. 17** Sonicity Fitzroy, selfie (© 2012, P. Johnson)

sometimes what is only a small spec of one's fashion sense in the real becomes a major defining fashion statement in the virtual (Fig. 17).

People cannot contain their experiences within virtual worlds as much as they believe is possible—human experiences, whether occurring in virtual or real life, contribute to one's character (and fashion sensibilities or non-sensibilities). Consider that one plugs into a virtual world directly, and this will become increasingly so the case. With Oculus Rift, such opportunities allow further immersion and less separation from body and self. Another consideration, raised by Tom Boellstorff (2010), in *Coming of Age in Second Life*, is the concept of "personhood." The notion of self is complicated by physical factors as well as the communities in which one exists. Would that not be exacerbated as one constructs parallel realities through multiple alternate avatars in one or more virtual worlds. Jim Blascovich and Jeremy Bailenson (2012, p. 5), in *Infinite Reality,* state, "One can wear an avatar of any gender, age, race, species, or shape; via the avatar, it is possible to meet others in virtual spaces without them having a clue about one's physical attributes and identity." Even as avatars, no one is inescapable from tracking technology and, as such, one's real identity is never truly anonymous. Nonetheless, the experiences of the virtual avatar become shaped by alternating and simultaneous first and third person points of reference. As technology evolves in allowing persons to sense through their avatar, seeing themselves projected and assimilated, they become an extension of humanity (think McLuhan) or maybe the avatar is merely wearable fashion—and as such, a technological elaboration of self within a reality that encompasses virtuality (alas, multiple realities).

In a video interview with *Designing Worlds*' hosts Saffia Widdershins and Elrik Merlin (2014), Linden Lab's CEO Ebbe Altberg discussed plans for Second Life and the company's beta virtual world being developed. A prominent thread of the conversation focused on improvements to avatar facial expression in Second Life. Altberg noted that eventually people would likely "transmit…real-world facial expressions onto [their] avatar." For now, he would be content to move toward that possibility. He explained that Second Life as well as others, like Philip Rosedale's *High Fidelity* (2014), had been investigating such technology. The idea that an avatar could be adorned with her personal taste in hair and make-up, dolled up in an evening gown or dressed for virtual success in designer business attire, with the perfect accessories on her customized mesh body, and then complete her look with the ability to smile, raise her brows, and perhaps wink is something that carries appeal for virtual world consumers and the creators and marketers of those platforms. Altberg ensures that flexibility and customization will remain key goals for his company. For the fashionista, Second Life has managed to catch the attention of real life designers, and has given in-world designers opportunities to experiment and hone their craft for future worlds and the real world that is becoming increasingly dependent on technology for design and creation. Kate Hartman (2014), author of *Make: Wearable Electronics,* in her preface states, "We're living in a moment where wearable technologies are just starting to become part of our everyday lives. They live on our wrists and in our glasses. They track our activities and transport us into virtual worlds. But this is just the beginning" (xi). The next virtual world might be the one that is worn as an accessory, a fashion statement, and perhaps serve as the connection to one's virtual persona customized for work and play.

## References


Beliveau, H. (2011, September 24). Fashion: Ethnic skins are only mature? *Second Life* Community forum. Retrieved March 13, 2014, from http://community.secondlife.com/t5/Fashion/Ethnic-skins-are-only-mature/td-p/1123455.

Betts, K. (2009, December 10). Will fashion's biggest names kiss the runway goodbye? *Time*. Retrieved October 22, 2010, from http://www.time.com/time/arts/article/0,8599,1946717,00.html.

Blascovich, J., & Bailenson, J. (2012). *Infinite reality: The hidden blueprint of our virtual lives*. New York: William Morrow Paperbacks. Reprint edition.

Boellstorff, T. (2010). *Coming of age in second life: An anthropologist explores the virtually human*. Trenton, NJ: Princeton University Press.

Bosah, E. (1998). *Cyberghetto or cybertopia: Race, class, and gender on the Internet*. New York: Praeger.

Boudreault, L., & Moser, J. (2012, October). Neutralizing identity: Exploring language and gender in a virtual world. *Digital Writing and Research Lab*. Series Number: 080218-2. Austin, TX: University of Texas. Reprint 2007: neutralizingidentity.pdf. Retrieved March 13, 2014, from http://www.dwrl.utexas.edu/content/neutralizing-identity.

Brooks, D. (2009, October 22). Virtual fashion economy helps imaginary life suck, too. *Crave Online*. Retrieved July 1, 2014, from http://www.craveonline.com/lifestyle/articles/142836-virtual-fashion-economy-helps-imaginary-life-suck-too.

Burns, M. (2009, November 2). The power of real-world gender roles in *Second Life*. *Pixels and Policy*. Retrieved July 13, 2013, from http://www.pixelsandpolicy.com/pixels_and_policy/2009/11/female-avatars.html.

Carella, C. (2007, May 14). *Top 25 brands measured by traffic*. The Electric Sheep Company. Retrieved July 11, 2009, from http://blog.electricsheepcompany.com/?author=4/?feed=rss2&p=232.

Chadwick, G. (2010, January 22). Fashion expands into the virtual market. *Financial Times*. Retrieved June 22, 2014 from http://www.ft.com/cms/s/2/baa55cea-06df-11df-b058-00144feabdc0.html.

Chavez, E. (2014, June 13). How naked are you? X.Pose wearable 3D printed sculpture bares all. *3D Printing Industry*. Retrieved June 26, 2014, from http://3dprintingindustry.com/fashion.

Coachman, D. (2010, February 1). Keeping it real. African American-owned companies look to change the face (and space) of virtual reality. *Black Enterprise*. Retrieved March 1, 2014, from http://www.blackenterprise.com/mag/keeping-it-real.

Cortes, P. (2010, June). Sanders Beaumont: International designer of the month. *GlanceMagazine*, pp. 28–33. Retrieved June 6, 2014, from http://issuu.com/glanceinternationalagency/docs/glancemagazine_june2010.

Delvalle, J. (2011, September 25). Fashion: Ethnic skins are only mature? *Second Life* Community forum. Retrieved March 13, 2014, from http://community.secondlife.com/t5/Fashion/Ethnic-skins-are-only-mature/td-p/1123455.

Digital Image. (2007–2012). Fashion forward. *Digital Image*. Retrieved July 30, 2014, from http://digitalimagefashion.blogspot.com.

Ensslin, A., & Muse, E. (2011). *Creating second lives: Community, identity and spatiality as constructions of the virtual*. New York: Routledge.

Everett, A. (2011). Have we become postracial yet? Race and media technology in the age of President Obama. In L. Nakamura & P. Chow-White (Eds.), *Race after the internet* (p. 165). New York: Routledge.

Fitzroy, S. (2012a, April 7). The secret life of dolls (Alles Klaar & Kynne Llewellyn). Photoshoot. *Second Life* exhibit at OrCafe. Retrieved July 1, 2014, from https://www.flickr.com/photos/soni4bosl21/sets/72157629765496827.

Fitzroy, S. (2012b, May). The secret life of dolls. *Best of SL Magazine*, pp. 65–88. Frolic Mills: *Second Life*.

Games for girls who love fashion. (2014). Games for girls, web directory. Retrieved July 30, 2014, from http://www.gamesforgirlswholovefashion.com.

Girls Gamsey. (2009). Best dress up games features: Top 10 list. *VR Fashion Blog*. Retrieved July 23, 2014 from http://vrfashion.blogspot.com/2009/02/best-dress-up-games-features-top-10.html.

Grunewald, S. J. (2014, July 18). Medieval Barbie with 3D printed battle armor may not be sold in stores but she should be! *3D Printing Industry*. Retrieved July 26, 2014, from http://3dprintingindustry.com/fashion.

Hartman, K. (2014). *Make: Wearable electronics*. Sebastopol, CA: Maker Media.

IMVU. (2014). *Information*. Web. Retrieved July 27, 2014, from http://www.imvu.com/about/faq.php.

Johnson, P. (2010a, November). Media, machinima and the virtual runway: The rise of fashionista in *Second Life*. *SCAN: Journal of Media Arts Culture*. Retrieved November 2014, from http://www.scan.net.au.

Johnson, P. (2010b). *Second life, media and the other society*. New York: Peter Lang.

Johnson, P. (2013). The virtual sky is the limit: Women's journalism experiences in *Second Life*. In D. Baldwin & J. Achterberg (Eds.), *Women and second life: Essays in virtual identity, work and play* (pp. 116–134). West Jefferson, NC: McFarland & Company, Inc.

Johnson, P. (2014, April 6). Constructing identities: Examining how the media builds, shapes, and reinforces our perceptions of minorities. Invited paper. Presented to the Broadcast Education Association, Multicultural & Gender Divisions, Las Vegas, NV.
Juneau, M. (2014). Mimi Juneau. *Flickr*. Retrieved July 24, 2014, from https://www.flickr.com/photos/mimijuneau/.
La Ferla, R. (2009, October 21). No budget, no boundaries: It's the real you. *New York Times*. Retrieved July 22, 2010, from http://www.nytimes.com/2009/10/22/fashion/22Avatar.html?_r=2&pagewanted=1&8dpc.
Leung, L. (2005). *Virtual ethnicity: Race, resistance and the world wide web*. Burlington, VT: Ashgate.
Ludlow, P., & Wallace, M. (2007). *The second life Herald: The virtual tabloid that witnessed the dawn of the metaverse*. Cambridge, NY: The MIT Press.
Magic, M. (2011, September 25). Fashion: Ethnic skins are only mature? *Second Life* Community forum. Retrieved March 13, 2014, from http://community.secondlife.com/t5/Fashion/Ethnic-skins-are-only-mature/td- p/1123455.
Molitch-Hou, M. (2014, July 16). Fashion conference sourcing to feature 3D printing. *3D Printing Industry*. Retrieved July 26, 2014, from http://3dprintingindustry.com/fashion.
Nakamura, L., & Chow-White, P. (2011). *Race after the internet*. New York: Routledge.
Naone, E. (2008, April 25). A new vision for *Second Life*: Linden Lab's new CEO outlines his plans to help *Second Life* mature. *Technology Review*. Retrieved July 12, 2009, from http://www.technologyreview.com/read_article.aspx?id=20678&pg=2.
Ohna. (2011, September 24 & 25). Fashion: Ethnic skins are only mature? *Second Life* Community forum. Retrieved March 23, 2014, from http://community.secondlife.com/t5/Fashion/Ethnic-skins-are-only-mature/td-p/1123455.
Park, R. (2013, October 16). 3D printing sound waves helps fashion designer get where he wants to go on Project Runway. *3D Printing Industry*. Retrieved July 26, 2014, from http://3dprintingindustry.com/fashion.
Polvinen, E. (2008, June 18). Virtual fashion – What is it? *Fashion Technology*. Retrieved July 1, 2014, from http://fashiontech.wordpress.com/2008/06/18/virtual-fashion-what-is-it.
Rodat-Savla, E. (2014, July 13). 4 ways wearable tech could change your marketing strategy. *Virtual Technology*. Retrieved by July 13, 2014, from http://fashiontech.wordpress.com.
Rosedale, P. (2014). *High fidelity*. Press. Retrieved October 11, 2014, from https://highfidelity.io/press.
Scofield, L. (2010, June). Bollywood story. *Glance Magazine*, pp. 83–91. Retrieved June 6, 2014, from http://issuu.com/glanceinternationalagency/docs/glancemagazine_june2010.
Rosenwald, M. S. (2010, March 8). Second Life's virtual money can become real-life cash. *The Washington Post*. Retrieved July 25, 2015, from http://www.washingtonpost.com/wpdyn/content/article/2010/03/07/AR2010030703524.html
Tapley, R. (2007). *Designing your second life*. Berkeley, CA: New Riders.
Terdiman, D. (2007). *The entrepreneur's guide to second life: Making money in the metaverse*. Indianapolis, IN: Wiley.
The Sims 4. (2014). *The Sim nation*. Retrieved July 30, 2014, from http://www.simnationblog.co.uk/p/the-sims-4.html.
Turkle, S. (2012). *Alone together: Why we expect more from technology*. New York: Basic Books.
Virtual Abilities. (2014). Website. Retrieved May 13, 2014, from http://www.virtualability.org.
Virtual Worlds for Tweens. (2014). Online games kingdom. *Web*. Retrieved July 27, 2014, from http://virtualworldfortweens.com.
Volino, P. (2000). *Virtual clothing*. Berlin: Springer.
Voyager, D. (2013, April). *Second Life statistics 2013, spring update*. Daniel Voyager. *Blog*. Retrieved March 13, 2014, from http://danielvoyager.wordpress.com/2013/04/02/second-life-statistics-2013-spring-update.

Voyager, D. (2014a, June 8). *Fashion for life in Second Life opens*. Daniel Voyager. *Blog*. Retrieved July 10, 2014, from http://danielvoyager.wordpress.com/2014/06/08/2014- fashion-for-life-in-second-life-opens.

Voyager, D. (2014b, April 1). *Second Life* statistics 2014, spring update. Daniel Voyager. *Blog*. Retrieved July 27, 2014, from http://danielvoyager.wordpress.com/2014/04/01/second-life-statistics-2014-spring-update.

Vuissent, A. (2011, September 24). Fashion: Ethnic skins are only mature? *Second Life* Community forum. Retrieved July 23, 2014, from http://community.secondlife.com/t5/Fashion/Ethnic-skins-are-only-mature/td-p/1123455.

Widdershins, S., & Merlin, E. (2014, October 6). *Designing worlds: Ebbe Altberg video and transcript*. Retrieved October 11, 2014, from http://modemworld.wordpress.com/2014/10/07/designing-worlds-ebbe-altberg-video-and-transcript/.

Winkler, S. E. (2009). *Designing dreams: Best practices for the art & business of avatar apparel design & development*. New York: Fashion Research Institute, Inc.

Winkler, S. (2012). *Fashion research institute*. Retrieved July 1, 2014, from http://shenlei.com/category/fashion-research-institute.

Yardley, J. (2014). Jo Yardley's Second Life: The adventures of a virtual time traveler. *Blog*. Retrieved July 22, 2014, from http://joyardley.wordpress.com.