Virtual reality in psychology and rehabilitation: the last ten years and the next!

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1. INTRODUCTION

Virtual reality (VR) has undergone a transition in the past 10 years that has taken it from the realm of expensive toy and into that of functional technology. Revolutionary advances in the underlying VR enabling technologies (i.e., computation speed and power, graphics and image rendering technology, display systems, interface devices, immersive audio, haptics tools, tracking, intelligent agents, and authoring software) have supported development resulting in more powerful, low-cost PC-driven VR systems. Such advances in technological "prowess" and accessibility have provided the hardware platforms needed for the conduct of human research and treatment within more usable, useful and lower cost VR systems.

At the same time, there has been a growing awareness of the potential value of VR by scientists and clinicians, in addition to the general public. While much of this recognition may be due to the high visibility of digital games and massive shared internet-based virtual worlds (World of Warcraft, Halo and 2nd Life), clinical research applications routinely come into the public consciousness via the popular media. Whether this can be considered as "hype" or "help" to a field that has a storied history of alternating periods of public enchantment and disregard, still remains to be seen. Regardless, growing public awareness coupled with solid scientific results delivered from VR clinical and research applications have brought the field past the point where skeptics can be taken seriously when they characterize VR as a "fad technology". It is not 1998 anymore!

When discussion of the potential for VR applications in the human clinical and research domains first emerged in the early-1990s, the technology needed to deliver on the anticipated "visions" was not in place. Consequently, during these early years, VR suffered from a somewhat imbalanced "expectation-to-delivery" ratio, as most users trying systems during that time will attest. The "real" thing never quite measured up to expectations generated by some of the initial media hype, as delivered for example in the films "The Lawnmower Man" and "Disclosure"! Yet the idea of producing simulated virtual environments that allowed for the systematic delivery of ecologically relevant stimulus events and challenges was compelling and made intuitive sense. As well, a long and rich history of encouraging findings from the aviation simulation literature lent support to the concept that testing, training and treatment in highly proceduralized VR simulation environments would be a useful direction for psychology and rehabilitation to explore. Since that time, we have seen the development of VR systems that have demonstrated added-value for addressing a variety of clinical conditions and research objectives including: fear reduction with phobic clients, stress management in cancer patients, acute pain reduction during wound care and physical therapy with burn patients, treatment for Post Traumatic Stress Disorder, body image disturbances in patients with eating disorders, navigation and spatial training in children and adults with motor impairments, functional skill training and motor rehabilitation with patients having central nervous system dysfunction (stroke, TBI, SCI cerebral palsy, multiple sclerosis, etc.) and in the assessment (and in some cases, rehabilitation) of attention, memory, spatial skills and executive cognitive functions in both clinical and unimpaired populations. To do this, scientists have constructed virtual airplanes, skyscrapers, spiders, battlefields, social events populated with virtual humans, fantasy worlds and the mundane (but highly relevant) functional environments of the schoolroom, office, home, street and supermarket. These efforts are no small feat in light of the technological challenges, scientific climate shifts and funding hurdles that many researchers have faced during the early development of this emerging technology.

So where have we been and what do we have to look forward to with a technology that shows no sign of withering on the vine! What has worked so far and where have we hit a wall? How has mainstream clinical thinking about VR changed over the years since Lawnmower Man, DisneyQuest or Dactyl's Nightmare? This ICDVRAT 2008 Keynote will provide a summary of the past in counterpoint to a brief review of the future. Where illustrative, examples of VR applications dating back to the 20th Century will be discussed

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along with an update as to where they are now and what might be in store for the future as the 21st Century continues to pick up steam! At worst, the talk will be a nostalgic walk down VR memory lane coupled with some harebrained schemes for the future. At best, it will be an insightful summary of what we have learned so far, and how that can be used to inform a realistic roadmap for how VR can positively enhance the future of clinical care and research!

2. WHAT HAS CHANGED?

2.1 Expansion and Evolution of Clinical VR Applications

Over the last 10-15 years, we have seen significant advances in both the technology and the thinking that supports Clinical VR application development. As the field has matured, a number of forces have converged to support the creation and evaluation of VR systems that have gone well beyond its entry "showcase" application area in exposure therapy for anxiety disorders. At that time it was quite natural that exposure therapy was the first area to find value in a VR delivery mechanism. In the mid-1990's, VR technology was still quite costly and knowledge of 3D-interaction methods and user interface design was scant among those interested in the clinical use of VR. However, exposure therapy applications were less challenging to develop since the interaction requirements were relatively minimal, and much to our surprise, the graphics didn't have to be exact replicas of reality to produce the desired level of anxiety arousal needed to support the therapeutic process of habituation. Early patients treated with VR for acrophobia were observed to approach very graphically limited "Indiana Jones" style plank bridges perched over deep ravines and were so "primed" for fear of such conditions that the necessary level of anxiety arousal was sufficiently present to begin to apply exposure therapy methods. Soon it was found that with repeated exposures to such cartoonish imagery, patients would show subsequent extinction of the fear response and that these reductions would carry over to the real world. Hence, the field of clinical VR was jumpstarted from successful systems that gave courage to the fearful!

Shortly thereafter, VR-dedicated companies such as Virtually Better, Inc. began to emerge from the union of Computer Scientists (i.e., Larry Hodges) and Clinical Psychologists (i.e., Barbara Rothbaum) driven by the early vision of creating such VR exposure systems for this slice of the clinical population. At the same time, other scientists and clinicians began to create alternative visions for how this "cool" technology could be used for the assessment and rehabilitation of cognitive/motor dysfunction in an ecologically valid and sometimes more motivating fashion. Although when compared to exposure therapy approaches, the technical requirements for tracking motor behavior and fostering natural interaction within virtual worlds were a bit more demanding in these areas, many of the primordial efforts to address those challenge started to appear at events like Medicine Meets Virtual Reality (MMVR) and the European Conference on Disability Virtual Reality and Associated Technologies (ECDVRAT) in 1996 (later changed to the ICDVRAT in 1998, to better reflect the growing International nature of the field!). Applications by Giuseppe Riva next emerged to provide body image visualization for those with eating disorders, shortly followed by Hunter Hoffman's seminal work with VR for pain distraction, which opened up a completely novel and important clinical application domain that somehow was missed by those who had come before! These historical clinical-conceptual events, in combination with the ever-accelerating growth in computational speed and power, set the stage for the birth of a VR application area which in reality could actually trace it conceptual roots back 70 years to the tinkering of an organ builder in Binghamton, New York (Edwin Link) leading to the creation of the first aircraft simulator − the Link Trainer.

2.2 The Past Sets the Stage for the Future

So by the start of the 21st Century, all the pieces were in place for the vigorous evolution of a new field of clinical and research science, all based on leveraging the core VR attributes that had been recognized during the early years as well matched to the needs of various clinical targets. In this regard, a growing legion of clinical scientists began to see VR, not so much as a Sci-Fi dream, but rather as a usable tool, that when wielded by the hand of a well-trained clinician, could enhance elements of exposure, distraction, motivation, visualization and measurement beyond what was available with the methods of the past. Since then, the field of VR has continued to expand to address a diverse range of clinical conditions and scientific questions that stand in stark contrast to what was being done a mere ten years ago. So what else has changed in the last ten years to make this all happen? In this one hour Keynote, I will try to briefly address what has changed the VR landscape over the last ten years and attempt to make some speculations about where we may be heading in the next 10!

Here follows just a few teasers …

- *Computational Speed and Power* – During the late 1990s, computing and graphics technology had advanced to the point where basic PC systems with new more powerful graphics cards could begin to serve as computational platforms for delivering immersive VR. Gone were the days of $200,000 Silicon Graphics reality engines that kept VR in the realm of research labs, out of reach of everyday clinicians. These advances in computing prowess were predicted indirectly in 1965 by Intel co-founder, Gordon Moore, who wrote a paper for Electronics Magazine predicting that the number of transistors that could be placed on an integrated circuit would double every two years. Although some say that this exponential increase (Moore's Law) occurs every 18 months, the end result has allowed for affordable processing power to meet the needs of innovative VR researchers. This continuous and predicted growth in processing power had finally balanced the VR expectation-to-delivery ratio that had previously hamstrung the imaginative visions of those in the field in the 1990's!
- *Game Industry Drivers* – There is no doubt that the recent growth in the interactive digital game industry arena will continue to drive developments in the field of Clinical VR. The gaming industry juggernaut's growth is evidenced by the fact that as of 2002, it had surpassed the "Hollywood" film industry in total entertainment market share, and in the USA – sales of computer games now outnumber the sale of books. And this digital "gold-rush" has driven technology and social developments well beyond early expectations. The impact of this can easily be seen in the areas of graphics techniques and horsepower, display technology and in the creation of novel interface tools, the evolution of which was directly driven by the economic growth of the game industry. Just one example of the game industry's impact on graphics – the original SONY PlayStation, released in 1995, rendered 300,000 polygons per second, while Sega's Dreamcast, released in 1999 was capable of three million polygons per second. The PlayStation 2 rendered 66 million polygons per second, while the Xbox set a new standard rendering up to 300 million polygons per second. Thus, the images on today's $200 game consoles rival or surpass those available on the previous decade's $50,000 computers. This is Moore's Law in overdrive when big money and market enthusiasm is on the line!
- *Graphics Hardware and Software* – In large part due to the economic drivers in the game industry, massive advances in graphics have pushed the field almost beyond the level where the term "graphic realism" really captures the point. By contrast, a more apt descriptor could soon be graphic unrealism! Such hyper reality can be seen in some of the latest offerings from the game development company Crytek. In their recently released version of the game In Crysis, a new level of graphic expression has been reached. A demo video from this group will be presented during the Keynote to back up this claim. However, while the game industry drives the latest and greatest to feed the public craving for better entertainment options, eventually this level of software filters it way down to content available in the Clinical VR domain. Perhaps one of the best examples of this is with the open source game engine "Ogre". Examples of this tool will also be presented during the Keynote. Finally, perhaps the most useful piece of software for the interests of our field is Giuseppe Riva's milestone (and free!) software tool called NeuroVR. Designed for folks who want to build virtual worlds without a degree in computer science, this tool gives you "starter" environments of many archetypic worlds relevant for Clinical VR and provides fairly usable options for modifying them to meet the unique needs of a wide range of applications.
- *Display Technology* – The eMagin head mounted display (HMD) and similar low cost options have now made this form of immersive VR accessible within the budgets of clinicians and fledgling VR scientists. With the advent of an integrated tracking solution with bright Organic Light Emitting Diode (OLED) displays, this HMD is now the workhorse of Clinical VR. Advances in stereoscopic flat panel displays and autostereoscopic system are also continuing to provide new displays options for applications where full immersion is not required, particularly in upper extremity motor rehabilitation and for cognitive assessment.
- *Low-Cost Interaction Devices* – Lower cost hardware is supporting this area and the big news comes in the form of low cost camera-based optical tracking solutions to support interaction methods. While there will always be a place for robotic and high end optical tracking systems (e.g. Immersion Corp., the Motek "Caren" system) for well-heeled clinical centers, a number of labs are now using off the shelf web cams to track upper and lower extremity movement that is embedded in game-like contexts for motor rehabilitation. And of course the Ninetendo Wii has engaged the public consciousness, driving SONY and Microsoft to take notice that humans do occasionally like to naturally interact with their game content. As well, the Wiimote interface has generated a buzz for its elegant simplicity as a 3D user interface and has been hacked for a variety of creative applications. However, a general word of caution is in order here. While a lot of groups like to bandy about terms like "Wiihab" and "Wiihabilitation", and in fact the Wiimote has shown value as an exergaming interface, to refer to any

activity afforded by an interface device as rehabilitation is misguided and requires a bit more thought. Rehabilitation tasks need to meet specific criteria and while it is easy to train flailing with a Wiimote, genuine motor rehab requires clear knowledge and specification of the target to be trained to inform the choice of interaction method and task design required to support precise motor action, albeit in a fun and engaging game context. Finally, while overshadowed by the excitement surrounding the Wii, the Novint Falcon force feedback system now offers a new set of options for game-based rehabilitation at a cost of less than an IPOD!

- *Virtual Humans* – As the underlying enabling technologies continue to evolve and allow us to design useful and usable "structural" clinical VR environments, the next important challenge will involve "populating" these environments with believable virtual representations of humans. Over the last ten years, the technology for creating virtual humans has evolved to the point where they are no longer regarded as simple background characters, but rather can begin serve a functional interactional role. More recently, seminal research and development has appeared in the creation of highly interactive artificially intelligent (and natural language capable) virtual human (VH) agents. No longer at the level of a prop to add context in a virtual world, these VH agents are being designed to perceive and act in a 3D virtual world, engage in face-to-face spoken dialogues with "real" people and other VHs in such worlds, and they are becoming more capable of exhibiting human-like emotions. Previous classic work on virtual humans in the computer graphics community focused on perception and action in 3D worlds, but largely ignored dialogue and emotions. This R&D will likely figure prominently in the dawn of "VR 3.0" and will be found to be vital in the creation of clinical training tools that leverage the use of VHs for clinical applications that address interviewing skills, diagnostic assessment and therapy training.
- *Psychophysiology and Imaging* – there is a rather compelling rationale for the integration of VR with human physiological monitoring and brain imaging for advanced research and clinical application. There exists a rich history of research in the disciplines of psychophysiology and neuroscience where the technology for recording bodily events in the least invasive fashion possible has evolved in order to capture and understand correlates of human mental and/or physical activity. Examples of such efforts would include the measurement of skin conductance, heart rate, electrical brain activity (electroencephalography), and brain structure and function (e.g., fMRI, DTI, SPECT, etc.) while a person attends to emotionally laden or cognitively challenging stimuli. While these monitoring technologies have existed for some time, the stimulus delivery media has remained essentially the same for many years, relying mainly on precisely delivered fixed audio and visual content. Although sophisticated display formats have been used in psychophysiology (i.e., tachistiscopes, projection systems, flatscreen computer monitors, etc.), these systems put significant constraints on naturalistic human behavior and interaction that may be relevant for studying research questions on integrated functional performance. The use of VR now allows for the measurement of human interaction within realistic dynamic 3D content, albeit within the constraints of the monitoring apparatus. The strength of VR for precise stimulus delivery within ecologically enhanced scenarios is well matched for this research, and it is expected that continued growth will be seen in this area. Such growth will likely occur with new Bluetooth enabled portable monitoring devices (e.g. Lifeshirt, Emotiv, Emsense) and with recent developments in the functional near infrared spectroscopy (fNIRS) area.
- *2nd Life and Beyond!* – While overwrought popular media exposure has caused 2nd Life to bounce around the Gartner Group Technology "Hype-cycle", alternating between the peak of inflated expectations and trough of disillusionment, there is no denying that internet-based social networking VR worlds that allow for avatar embodiment will continue to grow and have some impact on clinical care. Thus far, 2nd Life (and other similar worlds) have shown some value as a space to disseminate health and educational information, deliver some level of training and to provide gathering points for support group activity with clinical populations (e.g. stroke, TBI, Aspergers, etc.). The next questions to consider will involve an honest assessment of both the ethics and efficacy of using these spaces for the provision of clinical care.

These are just a few of the topics that I will attempt to concisely address in the ICDVRAT2008 Keynote and I thank the conference organizers for offering me this opportunity to spend some time sharing my views on how the past may inform the VR future! Space limitations preclude a full detailing of the references for what I have described above, but at the conference, I will make available a handout of all the references for the work cited. All references will also be made available on the ICDVRAT Archive.