The Potential for Virtual Reality to Improve Health Care©
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> *...Improving the health of European citizens and increasing the competitiveness of European health-related industries and businesses, while addressing global health issues including emerging epidemics. Emphasis will be put on translational research (translation of basic discoveries into clinical applications), the development and validation of new therapies, methods for health promotion and disease prevention, diagnostic tools and technologies, as well as sustainable and efficient health care systems.*
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> ***From the 7th Framework***

Virtual Reality (VR) has the potential to support and integrate the guiding themes of the European Commission's 7th Framework while improving health and increasing the competitiveness of European technology in the international economy.

Introduction:
Dr. Brenda K. Wiederhold, President of the Virtual Reality Medical Institute (VRMI), with offices in Brussels, Belgium, and Executive Director of the Virtual Reality Medical Center, with offices in San Diego, Palo Alto, and Los Angeles, California; is world renowned for her leadership in the field of VR. Working with European experts in the field, Dr. Wiederhold brings evidence to the European Commission on the integral role Virtual Reality (VR) must play to improve the health of European citizens and increase the competitiveness of European health-related industries and businesses.

Dr. Wiederhold is a licensed clinical psychologist in California and Switzerland, and has a doctorate in Clinical Health Psychology as well as national certification in both biofeedback and neurofeedback. She is a Clinical Instructor in the Department of Psychiatry at the University of California, San Diego and is president of VRHealth, a woman-owned healthcare company. In addition, she serves on the editorial board for several renowned publications, including *CyberPsychology & Behavior Journal,* the *International Journal of Virtual Reality,* and *Emerging Communication,* a book series by IOS Press. She also serves on the advisory board for the International Child Art Foundation, and the advisory committee for the California Science Center's exhibit on scientific and cultural aspects of fear.

Dr. Wiederhold serves as Chief Executive Officer of the Interactive Media Institute (IMI) and the Interactive Media Institute-Europe (IMI-E), non-profit organizations dedicated to furthering the application of advanced technologies for patient care. Under IMI, she began the first VR and behavioral healthcare symposium at the Medicine Meets Virtual Reality (MMVR) conference, growing this into an independent International Conference, CyberTherapy, now in its 12th year. CyberTherapy brings together researchers, clinicians and funders to share and discuss the growing field of CyberTherapy. This conference was originally a specialized symposium at the Medicine Meets Virtual Reality Conference featuring presentations that dealt primarily with conceptual matters and future possibilities. The symposium has continued to grow over the years in both size and scientific evidence and is now an independent three-day conference. The 10th annual CyberTherapy Conference, held in June 2005 in Basel Switzerland, highlighted the

largest program ever presented on controlled clinical trials of virtual reality and other cutting-edge technologies in the areas of mental health, rehabilitation, disabilities, training, and education. It involved representatives from 19 countries, reflecting its truly international character. In 2006, the Conference attracted over 200 attendees to Gatineau, Canada.

Dr. Wiederhold is recognized as an international leader in the treatment of anxiety, panic and phobias with virtual reality exposure and cognitive-behavioral therapy, and has completed over 5,000 virtual reality therapy sessions. In 2004 and 2005, Dr. Wiederhold was invited to address the National Institutes of Health in Washington, D.C. as one of the world's leading specialists in the field of VR treatment for medical illness. In addition, she has shared her insights as an invited speaker in Belgium, Canada, China, Croatia, Denmark, France, Germany, Israel, Italy, Korea, Luxembourg, Slovenia, Spain, Sweden and Switzerland on the topic of technology in healthcare.

Dr. Wiederhold currently has funded programs from the National Institute of Drug Abuse, NIH, National Science Foundation, Office of Naval Research, Defense Advanced Research Projects Agency, and Telemedicine and Advanced Technology Research Center in addition to serving as an unpaid consultant on several current research projects in Europe and Korea.

Dr. Wiederhold is currently completing her ninth book and has over 100 publications. Her current project, a collaboration with Dr. Giuseppe Riva of Milan, Italy, and Spanish researchers Rosa Banos and Cristina Botella, on their important work with the application of VR in the treatment of eating disorders and obesity, will help to form the basis for a **European network** for translational research on healthcare applications of VR technology.

What is Virtual Reality?

Virtual Reality (VR) is generally defined as a three-dimensional computer-generated world that can be explored interactively through a variety of computer peripheral devices. VR systems are configured to display the computer-generated world, or virtual environment, so that the image changes continuously depending upon the orientation and gaze of the user. In this way, the user may "walk" through a virtual building to explore different rooms, turn his head to "look around" a virtual airplane cabin and out the window, or navigate in a virtual outdoor environment of streets, buildings, fields and people. Because of this level of interactivity, the user begins to feel as though he is a part of the virtual world, actually experiencing it first hand. This is what is referred to as "immersion" or "presence." This makes VR much different from the non-interactive, passive action of watching a movie or video, and is much more immersive than playing a videogame (Wiederhold, 2004).

A VR system usually includes four major elements:

- A computer of at least 500 MHz with an advanced graphics card,
- A software program with the virtual environment,
- A tracking device that tells the computer where the user is looking based on head or body movement, and
- An image display system such as a large high-resolution digital display or a head-mounted display (HMD). HMDs project the computer image to the user through an

optical system which is worn as either a helmet or as a pair of glasses. The displays include small monitors and stereo earphones to provide both visual and auditory stimuli.

VR was initially developed for use by the military and entertainment industries, but has now found applicability in the medical and scientific fields. A wave of VR applications in medicine started in 1993, with VR displays being used to treat mental health disorders. Initially, VR cognitive behavioral therapy (CBT) was successfully employed to treat specific phobias, such as fear of heights. This application made intuitive sense, and it was a fortunate first choice, since most clinics still have above a 90% success rate today.

Virtual Reality is a medical tool.

Virtual reality is quickly finding wide acceptance in the medical community as researchers and clinicians become aware of its potential benefits. In the United States, significant public dollars have been invested in the research and development of VR technologies, especially by the military which views VR as a promising tool for both training and physical and psychosocial rehabilitation. "Recent advances in computer processor speed and graphics make it possible for even desk-top computers to create highly realistic environments," said Dr. Walter J. Greeenleaf at a conference hosted by the U.S. National Institute on Drug Abuse to highlight VR technologies in medicine. "The practical applications are far reaching. Today, using VR, architects design office buildings; NASA controls robots at remote locations, and physicians plan and practice difficult operations. Several pioneer research groups have already demonstrated improved clinical performance using VR imaging, planning and control techniques (Pueschel, 2004)."

Revolutionary health care applications have been studied for surgical procedures (e.g., remote surgery), medical therapy, preventive medicine, visualization of databases, skill enhancement and rehabilitation, and medical education and training (Vincelli, 1999). VR has also been shown to be highly effective as a psychotherapeutic tool. It is often used to distract patients during painful medical procedures (Sander, 2002. Perry, 1981. Hoffman, 2000a. Hoffman, 2000b. Hoffman, 2001a, Hoffman, 2001b. Hoffman, 2004. Thomas, 2003. Tse, 2003. Regera, 2004) or to provide graded exposure during treatment for a wider range of anxiety disorders Wiederhold & Wiederhold, 2002) including posttraumatic stress disorder (Hodges, 1999). VR can provide a blend of both distraction and experiential therapies that teach patients these techniques within a structured, safe environment.

The rapid advancement of technology combined with decreasing costs has propelled the VR field forward. Cutting edge VR systems have been designed to run on desktop and laptop personal computers, lowering costs to between € 6,275 and € 12,550 for a complete system. Real digitized images can now be introduced into virtual worlds, making it possible to replicate actual places, such as classrooms and family living rooms, in VR, increasing the potential to treat more mental health disorders including fear of public speaking, social phobia, and Attention-deficit/Hyperactive Disorder. By importing photographs of classmates, co-workers or family members into the virtual world, therapists can practice social skills with patients in the safety of a virtual environment before attempting interaction in the real world.

A wide field-of-view fiber optic image delivery system has made it possible to give people the illusion of being inside a virtual world while undergoing an fMRI brain scan. Researchers are beginning to combine VR with fMRI brain scans to the study of neural correlates of psychological disorders and to study the impact of therapy on patterns of brain activity. VR is an innovative technology that has a number of valuable healthcare applications worth exploring.

VR is a tool in translational research.
VRMC has demonstrated through its research that virtual reality systems provide valuable tools for the scientist to assure that his translational research is reliable, valid and replicable. VR environments allow for the repeated and systematic presentation of material to patients in a manner that is predictable, controllable, and reliable. VR can also simulate many situations that may otherwise be difficult to control for or simulate in real life, such as a fire emergency, resulting in ecologically valid and dynamic assessment and training. While controlling outside disruptions, VR can systematically introduce distractions. VR can be manipulated in ways that the real world cannot.

Patients who are experiencing VR can also be instrumented with non-invasive devices that accurately and objectively measure performance and physiological responses. VRMC has pioneered the use of sensors that record heart rate, heart rate variability (including very low frequency, low frequency, and high frequency spectral analyses), skin conductance, skin temperature, and respiration.. Easy-to-use protocols for placing sensors on individuals who enter virtual worlds have been developed and all sensors are interfaced to PCs so that data can be easily displayed in real time and collected for later analysis. This is done so that a patient's physiological reactions to the treatment can be objectified and compared with that same patient's self-reported subjective responses. Participants are often monitored throughout their VR immersion. Five-minute samples are taken prior to VR immersion, at the beginning of immersion, in the middle of immersion, at the end of immersion, and after immersion in VR is terminated in order to measure psychophysiological changes the patient may experience throughout the VR experience.

VR enhances exposure therapy.
VRMC researchers have demonstrated over the past decade that using VR to treat patients with psychological problems is one of the most promising practical uses of VR technology. For example, VR exposure therapy is proving valuable for treating clinical anxiety disorders. In exposure therapy, a patient uses relaxation skills to manage reactions towards feared situations. VR technology has allowed clinicians to treat patients more effectively and efficiently without concerns of excessive cost, loss of confidentiality, and limited safety that may arise with real-world exposure.

Prior to VR technology, exposure therapy was dependent upon the patient's ability to imagine a feared stimulus, a barrier to many who lack the necessary visualization skills. VRMC's virtual environments have allowed outreach to a group of individuals who were too overwhelmed with the thought of being "stuck" on a real freeway or on a 30-minute airplane flight to even attempt treatment. The prospect of VR exposure, which can be terminated with the mere removal of a head-mounted device, is far less frightening for many than the real-life alternatives. As they

exercise control over their own treatment, patients increase their level of self-efficacy, ultimately gaining control over their own lives.

VRMC's first use of virtual reality was with **fear of flying patients and progressed to other phobias and PTSD in motor vehicle accident survivors.** The need is high considering that 32 per cent of mental health dollars are spent on anxiety treatment while 33 per cent of people with insomnia, chest or abdominal pain actually have an anxiety disorder (Pueschel, 2004). Treatments such as **cognitive behavioral therapy (CBT)** teach patients to change their thought processes and then their behaviors. Prior to VR, therapists had to actually take their patients on a plane or get them to sit and visualize the experience that caused their anxiety in order to help them. VR made CBT more effective because it was no longer dependent on a patient's imaginary abilities and provided a structured environment, was less time-consuming, less expensive and safer. Our research has shown that VR does not require exact digital replicas of real world environments in order to elicit anxiety in patients. A more cartoonish VR world may force the patient to more actively engage his or her brain in order to "fill in gaps". (This active participation has been found to be necessary for therapeutic efficacy). Physiological monitoring during exposure through virtual reality informs therapists where the reaction starts so that they can help their patients control their anxiety more effectively.

Although traditional cognitive-behavioral treatments for specific phobias are successful for those who seek and complete treatment, the vast majority of phobics never seek treatment. VR allows clinicians to treat a larger proportion of phobics, and there is evidence that phobics find the thought of VR therapy less repugnant than in vivo therapy. Among other disorders, European researchers have shown VR exposure therapy to be effective in treating fear of heights, fear of spiders, fear of flying, claustrophobia, eating disorders, panic disorder and agoraphobia (Vincelli, Riva, and Wiederhold, 2002) and posttraumatic stress disorder (Garcia-Palacios, Hoffman, Carlin, Furness, & Botella-Arbona, 2002).

INTREPID, a VR project funded by the 6th Framework in recognition of the great potential of VR in the health arena, began work on the development of an intelligent multi-sensor wearable system for the treatment of phobias and situational anxiety. The system aims to incorporate emotional intelligence - via a biosensors fusion system able to sense the underlying phobic's states - and a virtual environment that, based on the machine's intelligent decisions, will virtually expose patients in situations that help them overcome their phobias. In addition, it plans to communicate with a healthcare professional's site to provide decision support concerning the patient's therapy. The INTREPID project has been limited in scope but may provide a platform on which to expand to wider applications and advanced economic opportunity of the technology.

VRMC has made significant contributions to the application of VR-enhanced exposure therapy in the treatment of **Post Traumatic Stress Disorder (PTSD)**, especially in returning soldiers. By approaching stressors in a controlled environment and discussing their feelings both before and after exposure, the afflicted can begin to work toward a place of increased peace and stability. Before VR technologies, doctors and therapists were forced to find more creative options for use in their sessions. This could mean using photographs or even just memories that the patient had refused to revisit. Now, virtual reality scenarios created using the latest in video game software can literally recreate scenes of battle.

In addition to presenting three-dimensional visual worlds through a head-mounted display, augmented VR can introduce a variety of other stimuli to enhance VR immersion including sound, vibration, currents of air, and olfactory stimuli. The government of the United States, through grants to the VRMC from its Office of Naval Research and the Telemedicine and Advanced Technology Research Center (TATRC), has invested significant resources to study the promising protocols involving VR therapy for military troops in both the U.S. and Poland, especially those returning from Afghanistan and Iraq. The governments of Canada, Australia, the United Kingdom, France, Denmark, Poland, Sweden and Rwanda have expressed interest in working with the Virtual Reality Medical Center to adapt PTSD products to their own populations.

VRMC, with the support of its European colleagues, is pioneering research in the United States on the application of VR-enhanced exposure therapy to **eating disorders and obesity**. Eating disorders are complex, chronic illnesses often resistant to most traditional therapies. The most common eating disorders - anorexia nervosa, bulimia nervosa, and binge eating disorder - are on the rise worldwide. All socioeconomic, ethnic and cultural groups are at risk. More than ninety percent of those with eating disorders are women. Further, the number of American women affected by these illnesses has doubled to at least five million in the past three decades.

It is estimated that six in 10,000 European women suffer from anorexia and 8.5 in 10,000 from bulimia, and this number is rising. Treatment for eating disorders varies widely across Europe. According to the European Medical Association, large urban areas have three times the number of sufferers per population size as people living in rural areas. That number is likely to be grossly underestimated, as in many areas in Europe, the problem is not recognized.

Obesity (defined as a Body Mass Index of ≥ 30) is rising at an alarming rate throughout Europe. It forms a pan-European epidemic that presents a major barrier to the prevention of chronic non-communicable diseases. At least 135 million EU citizens are affected and perhaps another 70 million in those countries seeking to join the EU. In many countries, significantly more than half the adult population is overweight and up to 30% of adults are clinically obese (International Obesity Task Force, 2002). As of 2000, the number of obese adults worldwide had increased to over 300 million (International Association for the Study of Obesity, 2003). Obesity increases the risk of many serious and fatal medical conditions, including heart disease, high blood pressure, diabetes, and cancer. Among people diagnosed with Type 2 (non-insulin-dependent) diabetes, 46% have a Body Mass Index of greater than 30 (the healthy range is between 18.5 and 24.9). In addition, 41.9% of men and 37.8% of women who are obese also suffer from hypertension. Obese individuals have a 50%-100% increased risk of death from all causes when compared with normal-weight individuals. According to Peter Kopelman of the Royal London School of Medicine, life expectancy of a moderately obese person could be shortened by two to five years.

Over the past five years, virtual reality environments have been successfully used to treat several different types of eating disorders. At least five controlled clinical studies have shown that virtual reality can significantly improve the positive effect of cognitive behavioral therapy in the treatment of obesity, binge-eating disorder, anorexia, bulimia, and body dysmorphic disorder

(Riva, 2006). Virtual realty therapy has been most successful when used as an adjunct to both in-patient and outpatient treatment programs. The original studies (Health Talk@Mac, 2004) using virtual environments have typically included rooms and scenes where the activities of eating and food preparation help to address patients' feelings or conflicts about nutrition. Other virtual scenes involving body image take advantage of a "virtual scale" and social scenes where patients compare their body and their perceived body image to external cues. The patient's actual body dimensions are scanned using a digital camera and introduced as an avatar into the virtual world. By comparing the perceived image to the body's actual image, the underlying body dysmorphic conflict or mismatch can be presented to the patient in a way that is both beneficial and therapeutic.

Dr. Giuseppe Riva, a research professor of psychology in Milan, Italy has pioneered the use of VR with clients who have distorted ideas about their own body shape. His analysis of published

data suggests that VR can help to address two key features of eating disorders and obesity that are not always adequately addressed by existing approaches: body experience disturbances and self-efficacy. His interventions are based on Integrated Experiential Therapy (IET), a relatively short-term, patient-oriented approach that focuses on individual discovery. Like Cognitive Behavioral Therapy, IET uses a combination of cognitive and behavioral procedures to help the patient identify and change maintaining mechanisms. IET focuses on the negative emotions related to the body and on supporting the empowerment process. Dr Riva conducted a study with 500 participants that found VR can augment obesity therapy by changing a patient's body imagery and by teaching coping behaviors around food (Thacker, 2003).

A recent study by Dr. Riva and his colleagues examined the use of the Integrated Experiential Therapy to treat patients with binge eating disorder and obesity in a controlled clinical trial. The results were very promising, especially VR treatment's effect on relapse rates. Six months after treatment, 77% of the patients who had used VR still had no binging problems, while only 56% of the group who had received traditional cognitive-behavioral therapy and 22% of the group that had received nutritional education still did not binge (Riva, 2006).

The ability to **fight smoking through VR** opens up a whole new world for those seeking treatment. VRMC is building an Internet-based VR world for teen smokers which will reach those that are not comfortable in face-to-face interventions. The Internet also reaches the youth on a personal level through a medium they are comfortable with using. It provides an informal and convenient support system in this fast-paced society. The Internet is relatively low-cost, is operational at any time, and can provide a multitude of health information for young adults.

Drs. Mark and Brenda Wiederhold are experts in the field of VR and have done several studies regarding smoking cues. In a study for nicotine craving, virtual environments contained different smoking cues such as a bar with a pack of cigarettes on the counter, or a party where someone offers a cigarette. Overall, the study determined exposure to virtual cues helped reduce cravings in those who were nicotine dependent. Dr. Brenda Wiederhold was also involved in a study

conducted in Seoul, Korea using fMRI to study cue-induced smoking cravings in virtual environments. With the help of the fMRI, Dr. Wiederhold was able to see how the brain reacted to the smoking cues, and which areas were most affected. Another study involving the Drs. Wiederhold showed that cue exposure techniques, which try to extinguish this learned association, have been increasingly promoted as a potential treatment for addictive behaviors, including cigarette smoking.

VR enhances distraction therapy.
For over a decade, the technique of distraction has been researched and successfully applied in clinical practice in order to reduce pain associated with certain medical procedures. The use of distraction is based on the assumption that there is an important psychological element in the perception of pain, with the amount of attention given to the harmful stimulus affecting the perception of the pain. Distraction techniques are based on the patient's limited capacity for attention, resulting in a reduction in the patient's attention to the stimulus and therefore a reduction in the stimulus itself. It was assumed that the ideal distractor would require an optimum amount of attention involving various senses (visual, auditory and kinesthetic), an active emotional involvement, and participation from the patient to compete with the signals of the harmful stimuli. One of the most important advantages of VR is the flexibility this tool allows clinicians during treatment. For example, the headphones on the head-mounted device (HMD) which project the sound of the virtual environment to the patient serve the added function of blocking out clinical noise that might sidetrack the patient in conventional distraction techniques. The duration of the immersion can be increased or decreased, depending on the clinician's needs and the length of the treatment. **VRMC is a leader in the on-going examination of VR as an adjunctive therapy for distraction from acute pain during painful and unpleasant medical and dental procedures.**

One way to help cancer patients to cope with **chemotherapy-related side effects** is through the use of distraction interventions. Some forms of distraction are inexpensive and presumed to be only minimally effective—as in the case of television viewing—and others have empirically demonstrated to be minimally effective—such as listening to music. VR provides distraction and improves interest and absorption by drawing the patient into a three dimensional fantasy world and by allowing the patient to independently move around in and interact with the VR world. In an early study of VR to treat nausea, 80% of 10 cancer patients reported a decrease in the frequency of vomiting and level of nausea. VRMC is working with patients at the Naval Hospital to create immersive environments to further test this hypothesis.

Such results will mean not only decreased suffering among chemotherapy patients, but possibly increased survival rates among the more than one-third of patients currently unable to tolerate full dose-intensity chemotherapy treatment (Associated Press, 2004). This system will be inexpensive both in initial cost (less than 7,000 Euros for a turnkey operation) and in facilitation cost, since the patients can start and operate the systems on their own, rather than requiring a therapist to be present to deliver the intervention.

In preliminary clinical studies, researchers have found that immersive VR distraction can reduce patient's pain ratings during **severe burn wound care** by 30%–50%. Relative to medications alone, patients receiving adjunctive VR during physical therapy reported large reductions in the

amount of time spent thinking about pain, pain intensity (worst pain), and in how unpleasant they found their pain.

A recent study conducted by the VRMC for the National Institute on Drug Abuse (NIDA) tested the efficacy of VR as a **distraction intervention for burn patients.** Participants in the study were 6 volunteers (2 women, 4 men) recruited from the patient population at Naval Hospital. All 6 participants reported a drop in pain while in the VR environment, and the magnitude of pain reduction from the VR compared to the pain focus condition was large (75.8%) and significant. VRMC is currently conducting an expanded controlled study with 180 patients at 6 sites in 4 countries. Exploratory hypotheses address maintenance of treatment effects across sessions, effectiveness of VR for both chronic and acute pain distraction, and uniform results across cultural boundaries.

In another NIDA research project, VRMC's objective was to test a custom-designed VR environment's effectiveness in distracting from the **pain of dental procedures**. Results showed that heart rates showed a statistically significant decrease during the VR session. Typically, a decrease in heart rate signifies a reduction in physiological arousal, and thus a state of relative relaxation in the participant. Skin conductance also showed a statistically significant decrease between during VR. A decrease in skin conductance also typically indicates a reduction in physiological arousal and an increase in relaxation in participants. Participants' exhibited similar temporal trends regardless of the order in which they experienced the virtual environments. This same software is now being used with chronic pain patients as well and shows initial positive results.

In addition to reducing pain associated with severe burns and dental procedures, VRMC is planning future immersive virtual worlds that encourage and motivate patients to perform specific therapeutic movements and to make **physical therapy** and wound care more bearable for patients. Reducing excessive pain also may reduce the stress experienced by the patient's family and health care givers. Opioid doses could one day be reduced for patients who respond well to adjunctive VR analgesia, reducing the opioid side effects.

Other applications of VR in pain management are being discussed among researchers in the United States and Europe. Steven Palter M.D., assistant professor and clinic chief of reproductive medicine in the Department of Obstetrics and Gynecology at Yale School of Medicine, reports that VR headsets are being used by women undergoing **in vitro fertilization** (IVF) under local anesthetic. His study has shown that women who wore a virtual reality headset during a painful surgical procedure for infertility found the soothing scenes and music greatly reduced their anxiety and discomfort. In tests conducted at Children's Hospital of Oklahoma, while undergoing **lumbar punctures**, adolescent cancer patients who wore VR glasses and watched a video said the VR glasses helped to distract them from the procedures. Subjects rated their pain as being lower when using VR glasses. VR has been considered by many as a distraction therapy for the acute pain of labor and delivery in **childbirth.** Like many conditions, patients and doctors are searching for ways to reduce the use of drug therapies which may have long term side effects impacting both mother and baby. The same conditions that have made other VR distraction therapies successful have huge potential in palliating the excruciating pain associated with giving birth.

VR is a tool for physical and cognitive rehabilitation.
One of the newest and most exciting applications of VR is in the field of rehabilitation. In cognitive rehabilitation, VR can be used for vocational training and as a way to train cognitive tasks in brain damaged patients. VRMC's research with VR in the field of motor rehabilitation includes applications for stroke, acquired brain injury, Parkinson's disease, orthopedic rehabilitation, balance training, wheelchair mobility, and training in functional activities of daily living. Research in VR applications for stroke patients in particular have made considerable progress; fMRI studies of VR used in conjunction with traditional physical therapy in stroke patients have resulted in neuroplastic changes in the brain and corresponding improvements in motor functions. Further research has studies the application of VR-enhanced rehabilitation with developmentally delayed and autistic children.

There are many reasons that VR applications are so effective. VR, for one, is an interactive, experiential medium. In the same way that computers are grasped intuitively by children and teenagers, users become directly engaged with the effects of the VR experience. Another reason is that VR is a unique setting where patients can explore and act without feeling threatened. Patients can make mistakes without fear of dangerous, real, or humiliating consequences. VR allows people with intellectual disabilities to explore environments without the distracting or restricting presence of other actors. Unlike human trainers, computers are infinitely patient and consistent. VR can also simulate many situations that may otherwise be difficult to control for or simulate in real life, such as a fire emergency, resulting in ecologically valid and dynamic assessment and training. While controlling outside distractions, VR can systematically *introduce* distractions; using this in a virtual classroom has allowed researchers to diagnose ADHD in children. VR can be manipulated in ways that the real world cannot. For example, VR can convey rules and abstract concepts without the use of language or symbols for patients with little or no grasp of language.

In motor rehabilitation, there are essentially three major advantages that VR offers over traditional therapy alone. One is that VR allows a safe, controlled environment for repetitive practice, and repetitive practice is crucial in learning motor tasks. The second is immediate, real-time feedback about performance. The third is, because of its interactive nature, VR can increase motivation by making the experience fun. Patients are much more motivated to complete exercises when presented with an engaging virtual reality video game environment than simply gym equipment. In addition, virtual treatments can be individualized to each patient and monitored to test his or her ability to perform certain tasks over time (Burdea, 2003). Progress is documented, and, as patients begin to develop strength and coordination, the tasks can be made increasingly more difficult, creating challenge and continual rehabilitation. Augmenting rehabilitation medicine with VR permits impaired individuals to explore worlds not otherwise available to them, allows accurate assessment and therapy for their disabilities, and helps architects understand their critical needs in public or personal space.

The possibility of VR tele-rehabilitation is another advantage of VR. The delivery of medical rehabilitation services, such as VR rehabilitation therapy, to a patient's own home via the Internet would be beneficial to those who live far from the nearest rehabilitation facility or who have trouble securing transportation to such a facility. VR could be combined in such a way that patients could interact with other patients and see each other's rehabilitation progress from the

comforts of their own home. Such a system would hold many potential advantages; the presence of other people would increase compliance, improve the quality of life, reduce depression, and reduce social isolation.

VR can assist the brain's ability to reorder neural pathways in response to new experiences or needs. **Neuroplasticity** processes are assisted with VR simulations that enable patients to work through the process of regaining skills in small and achievable segments. VR can break a skill down into discrete tasks – difficult in real life but easy in VR – and simulate repetitive increments more efficiently than live training. VR provides the opportunity to present specific and controlled stimuli to patients, as well as advanced methods for recording responses Studies have shown that what the patients learned in the virtual reality was transferable to real life.

Haptics technology allows for tactile interactions in VR, giving the user the ability to grasp and manipulate virtual objects. The manipulation of virtual objects is accomplished with the use of a "data-glove," a flexible glove with both tracking and movements sensors embedded in the material. Haptics-VR allows researchers to custom-design the virtual environment so that it targets specific motor skills in patients. In a pilot study, patients who had weak lower extremity muscles improved the strength capabilities of some of their ankle muscles when they used a haptics-based ankle rehabilitation system Studies with VR/haptics rehabilitation have shown improvements in the upper extremities as well. For example, one patient suffering from left arm paresis improved fine manual dexterity, grip force, endurance, and motor control of his affected area after playing a 3D game with haptic feedback

VRMC's partner, The Media Convergence Lab (MCL) at the University of Central Florida's Institute for Simulation and Training (UCF / IST) in Orlando, has recently developed haptics-based rehabilitation utilizing a mixed reality system involving multiple senses and conducted a case study examining the benefits and shortcomings of the technology. It is this equipment that the Virtual Reality Medical Center (VRMC) will utilize to rehabilitate patients with upper extremity injuries. VRMC and MCL/IST have arranged a strategic, signed business agreement such that VRMC will license this technology for medical and clinical use.

VR is a resource for surgical planning and performance:
For the discipline of surgery, the surgical console is the interface between the real and the information world. From the console, the surgeon can perform open surgery, minimally invasive surgery, remote tele-surgery, surgical pre-planning, surgical procedure rehearsal, intra-operative image guided surgery and surgical simulation. All these actions are possible from the single point of the surgical console.

VR surgical simulation development has been concentrated on Minimally Invasive Surgery (MIS)-partly because the paradigm for MIS already involves a physician looking at a monitor. An MIS simulation involves putting the instruments through openings and displaying a computer generated model overlaid upon visuals of surgical representations. Organs for VR surgery not only look like real organs, and they should act like real organs. Research is underway to even add smell to VR surgical simulations.

A VR surgical planning device takes actual physical data from an individual patient and combines it with computer-generated data. It incorporates real-time interaction with computer graphics that mimic a patient's anatomy. This is then used to make a simulation that will help plan and rehearse a surgical procedure - both for training and advanced planning of an operation.

Data fusion, the fusion of virtual patients onto real patients as a navigational aid in surgery, is the newest frontier of VR application in surgery. Eventually, medical care with multiple professionals will be provided in a shared virtual environment that incorporates shared decision making for an actual surgical intervention or a rehearsal.

VR is a tool in prevention of physical and emotional illness.
The many manifestations of virtual reality coupled with their ability to objectively monitor medical and psychological conditions support the promotion of effective healthcare and disease prevention. VR has proven its ability to **increase access to healthcare** by providing methods of intervention to populations who would not or could not take advantage of traditional avenues to care. **Quality of care** has improved with the objective measurements of success in discrete increments and overall cure rates. Because VR can be delivered through laptop computers and internet platforms, it is available "anytime, anywhere" and can be customized to a wide range of symptoms and stages of disease. It has proven to be a pleasant adjunct to traditional treatments and, as such, motivates and encourages patients to engage in and complete difficult therapies.

Science is constantly learning about the impact that **stress** has on overall health. Stress is or may be a contributing factor in everything from backaches and insomnia to cancer and chronic fatigue syndrome. One of the best strategies for dealing with stress is learning how to relax. However, relaxing is difficult to achieve in typical real world situations. **Stress Inoculation Training** (SIT) is a technique to help "inoculate" individuals to future potentially traumatizing stressors. Deployed personnel must often perform in extremely stressful environments, and optimum performance under such conditions requires the management of physiological, psychological and emotional responses to stressful stimuli. During preventive SIT, military personnel "experience" highly stressful situations in a virtual environment while being physiologically monitored. Repeated exposure enables performers to gradually become desensitized to stimuli that may initially elicit such strong physiologic arousal that performance is impeded and psychological trauma is more likely.

VRMC has provided VR-enhanced SIT to more than **11,000** military personnel in order to reduce the incidence of PTSD. The training follows a protocol used at the Naval Hospital and Camp Pendleton 1st Marine Division. In this approach, patients use biofeedback to learn how to relax their bodies and cognitively attend more fully in the moment. After this is achieved, troops are placed in the virtual environment (e.g., combat exposure, firefights in Fallujah, convoys, medical treatment tents). First neutral, and then progressively combative scenarios are presented and their physiological and subjective arousal is measured. The outcome is "hardened" troops prepared to handle difficult combat scenarios, even though they have never actually experienced them before.

SIT is being provided by VRMC to Polish troops who are part of the Coalition fighting in Iraq. SIT has been demonstrated to help prevent or reduce rates of PTSD in returning troops. A group

of 106 male British soldiers preparing for a 6-month tour of duty in Bosnia received a combination of pre-deployment stress training in combination with psychological debriefing and demonstrated a drastically reduced incidence of PTSD and other psychopathology approximately 10 times less than figures reported from another military samples (Deahl, et al, 2000).

Tobacco is the single largest cause of avoidable death in the European Union accounting for over half a million deaths each year and over a million deaths in Europe as a whole. It is estimated that 25% of all cancer deaths and 15% of all deaths in the Union could be attributed to smoking (Europa, 2006). Recent updates of indirect estimates of global tobacco mortality indicate that in 2000, 5.0 million premature deaths were caused by tobacco. About half (2.6 million) of those deaths were in low-income countries. Males accounted for 3.7 million deaths, or 72 percent of all tobacco deaths. About 60 percent of male and 40 percent of female tobacco deaths were of middle-aged persons (ages 35 to 69).

In high-income countries and former socialist economies, the 1 million middle-aged male tobacco deaths were largely composed of cardiovascular disease (0.45 million) and lung cancer (0.21 million). In contrast, in low-income countries, the leading causes of death among the 1.3 million male tobacco deaths were cardiovascular disease (0.4 million), chronic obstructive pulmonary disease (0.2 million), other respiratory disease (chiefly tuberculosis, 0.2 million), and lung cancer (0.18 million) (Disease Control Priorities Project, 2006).

The **prevention of smoking** is one of the world's greatest healthcare concerns. The Virtual Reality Medical Center (VRMC) is currently under contract with the National Institute on Drug Abuse (NIDA) to produce an Internet-based VR game aimed at adolescents that will guide smokers through several rooms and scenarios containing smoking cues. Teens will then learn how to face the cues and urges to smoke, and overcome them. In addition VRMC has a business agreement in place to deliver this program to Department of Defense dependents via DefenseWeb's Xtendable Server (a .NET open standards modular application platform and content management system developed specifically to meet the changing requirements of the Department of Defense. Through this VR game, adolescents will be provided with an engaging tool to beat their smoking addiction and prevent a lifelong habit with significant health consequences.

VRMC been commissioned to work with **"Renasterea Romania"** Cultural Foundation to develop and implement a smoking prevention program for high school aged youth in Romania. The project will be piloted in Iasi County where there are over 150,000 pupils in more than 350 schools.

VR is a diagnostic tool.

The capacity of virtual environment technology to create dynamic, interactive, three-dimensional stimulus environments, within which all behavioral responding can be recorded and measured, offers clinical assessment and intervention options that are not available using traditional methods. Technology for **diagnostic imaging**, compared to the other medical specialties, is large and well developed. Simulated three dimensional reconstruction of organs from radiological cross sections has become an important diagnostic tool by providing clinicians with a more naturalistic view of a patient's anatomy. The latest generation of these systems has the

capability to collect large amounts of high-resolution data but lacks the sophisticated software to easily navigate through this data. Adding interactive 3D visualization software to the existing hardware base provides value by reducing personnel time and costs and improves clinical efficacy. The imaging modalities that represent computer-aided applications of VR in radiology include CT, MRI, x-ray imaging NM, ultrasound and computed radiography.

Virtual reality has singular application in the field of **fMRI**. VRMC is testing its **custom-designed goggles** that can withstand the magnetic environment of the technology and display virtual images and environments as the fMRI records brain response to the stimuli. Data collected will reveal the level of a patient's immersion in the virtual world as well as the specific part of the brain triggered by the sensory cues.

VRMC has worked in the field of **hyperspectral imaging** technology that has been used to detect cancerous and precancerous abnormalities in human tissue in all areas of the human body accessible through endoscopy. The 3-dimensional optical imaging system employs high spectral resolution and narrow bandwidths to create highly detailed imaged that distinguish cancerous tissue from healthy tissue. A comparison of these tissue segments and cells permits diagnosis and delineation of suspect tissue.

VRMC has pioneered the use of **physiological monitoring** to collect real time data depicting patients' level of arousal while in virtual reality. Physiological monitoring serves as an objective measure of symptoms for the purpose of disease diagnosis. In addition to the subjective self-report measures, the VRMC's patients' physiological responses to exposure to virtual environments are monitored with non-invasive sensors that record ECG, EEG, skin conductance, skin temperature, and respiration measures using commercially available systems. All sensors are interfaced to PCs so that data can be easily displayed in real time and collected for later analysis.

Virtual reality may one day be the preferred method of diagnosing and rehabilitating **attention deficit hyperactivity disorder (ADHD)** among students, according to a researcher from the University of Southern California who is investigating the use of virtual reality therapy in a number of clinical applications. For this ADHD diagnosis, a child sits at a physical desk wearing a head-mounted virtual display. Generally, tests for ADHD involve behavior observation or questionnaires, with no direct control over the stimuli. Because virtual-reality technology is immersive, interactive, and computer-generated, the tester can control the environment completely. The technology also can distinguish between video and audio distractions. The VR world can systematically record reaction to controlled stimuli in an automated environment. Logically and rationally, virtual reality environments will be better at testing and assessing than their random, uncontrolled counterparts.

A **vestibular disorder** occurs when the vestibular system, which provides us with sensations of our body's motion and orientation in space by responding to the flow of fluid through canals located in our inner ear, is not functioning properly. If this system, for whatever reason, begins sending inconsistent cues that disrupt a person's ability to function under normal circumstances, a vestibular disorder is diagnosed. Patients often experience symptoms similar to panic attacks while driving. To determine whether the problem is a vestibular disorder, patients are immersed in a virtual environment complete with a real car seat, seat belt, gas and brake pedals, and

steering wheel in front of a large screen. The scene projected in front of them simulates driving down a freeway. Often motion of this type will aggravate a vestibular disorder, allowing it to be diagnosed. Patients who become cybersick (side effects such as dizziness and nausea related to exposure to VR) are referred to an Ear, Nose, and Throat physician to be treated for a vestibular disorder.

"Telemedicine" is broad term and refers generally to the use of information technologies such as satellite transmission, video conferencing or electronic data transfer for healthcare education, consultation, and delivery. Telemedicine overlaps Virtual Reality in the use of **'telepresent' medical experts** who have the ability to act and interact remotely from a patient by making use of VR technology. Ideally, this will reduce the cost of medical practice and bring expertise into remote areas. Telemedicine will also include telesurgery- the provision of VR-based systems to enable telepresent surgeons to perform surgery on remote patients.

VR supports the development of sustainable and efficient healthcare systems.
Sustainable and efficient healthcare systems require well-trained practitioners who have access to cost effective equipment, therapies, and partnerships that promote consistent, state-of-the-art treatment to patients anytime, anywhere. Under the current medical educational model, doctors-in-training learn their craft during training periods known as residencies. This model of learning by doing, or "see one, do one, teach one," has been the standard for more than 100 years and is dependent upon patient flow and the availability of high-quality instructors. It fails to guarantee that a trainee gains experience in all of the vital areas, nor does it provide an objective measure of a doctor's abilities.

VR-based instruction is now being used to train a broad range of individuals—from medical care professionals, such as in anatomy instruction and surgery simulation,, to teenagers in driving. Unlike human trainers, computers are infinitely patient and consistent. VR can also simulate many situations that may otherwise be difficult to control for or simulate in real life, such as a fire emergency, resulting in ecologically valid and dynamic assessment and training.

VR is increasingly being used in **medical training and education**. Applications focus on the use of three-dimensional inter-active graphics to give the students and clinicians a much better feeling for and understanding of anatomy than can be gained by looking at two-dimensional pictures or by reading text. Computerized three dimensional atlases of human anatomy, physiology, and pathology are about to revolutionize the teaching of these subjects. In the United States, advancements in digital image storage, retrieval, and manipulation, made accessible by the National Library of Medicine's Visible Human project, have produced an online resource from which VR systems continue to be developed and commercialized. Unlike textbook examples, VR simulations allow users to view the anatomy from a wide range of angles and "fly through" organs to examine bodies from the inside. VR would can useful in teaching procedures involved in breast and genitalia exams in which it is difficult to find subjects. VR saves money and improves testing in examinations that assess manual skills.

VR is especially applicable in simulations for **surgical training.** A visual environment showing anatomic structures is experienced and changes within the field of view in accordance with the actions taken using the virtual instruments (and with changes in the field of view). Such an

approach is useful in learning the basic surgical maneuvers. This environment allows for unlimited practice, limited only by the realism of the virtual surgical field, until the trainee-surgeon demonstrates sufficient manual and visuospatial adaptation to warrant treating actual patients.

Virtual reality applications in surgery are mediated through the **computer interface** and as such are the embodiment of VR as an integral part of the paradigm shift in the field of medicine. VR surgery systems consist of two components, the surgical workstation and remote worksite. At the remote site there is a 3-D camera system and responsive manipulators with sensory input. At the workstation there is a 3-D monitor and dexterous handles with force feedback. The VR surgical simulator might include a stylized recreation of the human abdomen with several essential organs. Using a helmet mounted display and a data glove, a medical student can learn anatomy from a new perspective by "flying" inside and around the organs, or can practice surgical procedures with a scalpel and clamps.

VR allows surgeons to practice hundreds of procedures prior to patient contact-and the practice carries no risk to live patients. Since doctors with less experience are in general more likely to produce errors, VR simulations could theoretically reduce physician error. VR will also reduce the high costs of training resources such as lab animals and physician's time and increase surgeon proficiency and thereby decrease the number of mal-practice suits. The most profound change is that the simulators can now be used to set criterion which the students must meet before operating upon patients. The expert (or experienced) surgeons perform on the simulator; their score is the benchmark which the student must achieve before being allowed to operate. Students do not train for a given period of time (eg, 10 trials on the simulator, or for 2 days); instead they must train until they reach the same performance (criterion-based or proficiency-based) as the experts. Some take only a few trials, while others take much longer – however no student operates upon a patient until they perform as well as an expert.

Trauma response skills and experience are important in the successful resuscitation and operative care of injured patients. Lack of training opportunities makes it difficult for medical care providers to learn and maintain these trauma care skills. Studies have demonstrated that virtual reality trauma simulators are likely the best long-term answer to this problem.

VRMC is developing trauma training programs with support from the U.S. government's Telemedicine and Advanced Technology Research Center (TATRC) as part of a commitment to support the development of commercially viable products that will ultimately meet the needs of both military and civilian populations. Since 1999, TATRC's medical technology program has supported the research and development of medical products and procedures that apply physiological and medical knowledge, advanced diagnostics, simulations, and effector systems integrated with information and telecommunications to enhance operational and medical decision-making, improve medical training, and deliver medical treatment across all barriers. The program scope is to identify, explore, and demonstrate key technologies and biomedical principles required to overcome technology barriers that are both medically and militarily unique.

The U.S. military is investing millions of dollars on training for soldiers, yet the methods for training combat medics continue to leave a void in their preparation. While static virtual sets and real-world training scenarios are being employed, they are not providing the soldiers with full immersion into combative medical situations. **VRMC's Combat Medic,** an interactive virtual reality video game (VRVG), has been demonstrated to prepare combat medics to produce better results in real-world testing than those receiving traditional training methods. The purpose of the VR video game is to provide an inexpensive training tool that allows medics to experience situations outside of their everyday training. The game tests the medics' knowledge of medicine, combat training skills and ability to function under the pressure of a battlefield situation. The video game contains virtual scenarios of terrain the medics are not able to experience in real-world training. It allows medics to learn from their mistakes and repeat scenarios until they successfully compete the task. When medics reach an injured soldier, they are given a closer view than in other games. The medic is able to turn the soldier over to examine bullet exit wounds or to tie on a tourniquet. The VRVG is interactive for the medic; for example, the mouse acts as scissors when it is necessary to cut off the soldier's vest to better see the wound, or become hands to tie on a tourniquet.

The game replicates the stressful environment of warfare and requires medics to perform under dangerous and complicated conditions. Testing financed by the U.S. Defense Advanced Research Projects Agency (DARPA) project for soldiers has shown that training does transfer from a video game to real-world simulation training. Game enhancements are planned to tailor the game to military surgeons, aeromedics, emergency room physicians and other trauma-related environments. Combat Media is an example of the type of video-game adaptation that is being financed and tested by all branches of the United States Military. Games that accurately simulate the real-world environment provide a low cost alternative that better prepares inexperienced soldiers to save their own lives while saving the lives of others.

Communication networks have the potential to transform virtual environments into shared worlds in which individuals, objects and processes interact without regard to their location. In the next five years, such networks are predicted to merge VR and telemedicine applications, allowing us to use VR for distance learning, distributed training and e-therapy. Today military medics are using hand-held computers with entire medical references and which can download the information from a soldier's "electronic dog tag" into the computer right on the battlefield. Now the medic "knows everything, about medicine and the patient". In addition, once the wounded soldier is placed upon the Life Support for Trauma and Transport (LSTAT), which is a portable intensive care unit (ICU), the surgeon back in the Mobile Advanced Support Hospital (MASH) can receive by telemedicine the vital signs, and even change the respirator settings, control the flow of the intra-venous fluids and medications. The LSTAT has been used since 2000 in the conflict in Bosnia and Kosovo. From the time of wounding when the soldier is placed on the LSTAT, to the helicopter evacuation, to the ambulance transfer to the MASH, to the emergency triage, to the operating room and finally in the post-operative ICU, the casualty is continuously monitored and the medical record is automatically recorded. In the Afghanistan and Iraq Wars, the LSTAT was recalled for servicing, however the medics would not send them back because they were so valuable.

Why VRMC?
The Virtual Reality Medical Center continually investigates new uses for VR in improving human performance. One of the things which sets our work apart is our continual emphasis on objectification through careful physiological monitoring during VR therapy and training, as well as additional testing in the real world setting to ensure a transfer of skills from the simulated world has indeed occurred. In addition, we work in multi-disciplinary teams to ensure that each part of the problem is appropriately addressed by a subject matter expert. The combination of these elements gives our systems and their users a critical edge.

VRMC's Product Development Team specializes in creating simulation software and virtual reality systems to facilitate medical therapy. The mission of PDT is to create, test, and deliver the highly effective virtual reality systems using innovative technology integrated with medical science. Having extensive knowledge in the creation of interactive software for clinical treatment, our graphics and software teams are skilled in the development of interactive 3D worlds using variety of cutting edge development tools. The products VRMC is currently developing range from various pain distraction tactics to clinically validated anxiety treatments. The products include Airport and Flight VR, Fear of Heights VR, and Virtual Reality Pain Distraction. The Product Development Team also supports military medicine by providing PTSD treatment, Stress Inoculation Training, and Combat Medic VR training systems for military medical personnel.

For more than a decade, Dr. Brenda Wiederhold and Dr. Mark Wiederhold have been critical players in the effort to exploit virtual reality technology to benefit their combined passions: improvement of the citizen's individual mental and physical health through technology. They have participated in national and international symposia on the subject and exchanged insights and findings with every player in the medical technology arena. In that process, they have met and collaborated with Europe's leaders in VR research and have hosted conferences and workshops across the Continent. Their current project, a book that chronicles existing knowledge of the application of virtual reality in the treatment of eating disorders and obesity, is a joint project with Dr. Giuseppe Riva of Italy and other European contributors.

For over a decade, the Wiederhold's have had formal collaborations with colleagues in Europe and Asia. To show further commitment to these collaborations, in 2004, VRMC established an official presence in Basel, Switzerland. In 2006, this expansion continued with the formation of a European corporation in Brussels, Belgium: **Virtual Reality Medical Institute**. This corporation will serve to more effectively allow for the exchange of ideas and promotion of the use of technology in the rapidly changing eHealth environment. Dr. Brenda Wiederhold is committed to the creation of a European network that continues to encourage EU researchers to contact US experts as well as venture capitalists in an effort to fund innovative research concepts and bring them to successfully to market. The *CyberTherapy Conference* will return to Europe once again in 2009, in addition to a more specialized meeting being planned in Austria, *Wounds of War: Reducing Suicide Risk in Returning Troops*, scheduled for October 2007. With unparalleled experience in the field, VRMC is in a position to jump-start the technological transformation of healthcare in Europe in ways that enhance all aspects of the goals of the European Commission's 7th Framework. We stand committed to helping the commission achieve their goals to improve the healthcare of all citizens.