

# Introduction

by

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In 1984, one warm summer night, around 2:00am, in downtown Palo Alto, I had an epiphany. A less ornate way of describing the experience would be to say that it was an *impactful realization*. The concept and the implications of this realization stunned me into silence for minutes, lurked in the background of my thoughts for weeks, and altered my life in a very dramatic way.

Perhaps it was due to my sleep-deprived state and that edgy-energized feeling that can roll over you after midnight. Or perhaps it was the euphoric feeling caused by walking into an all-night diner after midnight and finding they had not run out of key lime pie. Either way, a feeling of elation and energy set the tone for a discussion that night with one of my best friends, Jaron Lanier. Our discussion changed my perspective on computer technology, altered my career path, and propelled me to focus my research efforts toward developing next-generation medical systems that leverage virtual reality technology. In many ways, that conversation, which took place nearly four decades ago, spawned the book that you are now reading.

At the time, I was a graduate student in my twenties, working on my doctoral dissertation in neuroscience at Stanford University. Jaron and I both liked to stay up and work late into the night, often meeting at odd hours. Jaron is known as the visionary who coined the term "*Virtual Reality*" and started the first company (named VPL Research) to develop and provide commercial virtual reality systems. Jaron and his co-founders developed the concepts and enabling technology that serve as the foundations for the virtual reality (VR) and augmented reality (AR) systems that we use today.

Jaron had called me late in the evening and mentioned that he had been invited to contribute his ideas to an article to be published in *Scientific American*. However, he was stuck and severely delayed in writing up the material for the article. Jaron was worried that he would miss the opportunity. I immediately said, "Let's meet. We can talk it over, and you can write it up on the spot, and I'll have the benefit of hearing your ideas." I grabbed my Macintosh computer and rushed to meet Jaron at that all-night café named *The University Creamery* in downtown Palo Alto.

By the way, I felt very fortunate to have had that computer. The Apple Macintosh had just been introduced, and they were in extremely limited supply, available only via a lottery system at major universities like Stanford. Another friend of ours, Daniel Kottke, had been on the original Macintosh team, so Jaron and I knew a lot about the Macintosh and its pioneering graphical user interface. However, very few people actually had one. After all these years, I still recall how excited I was to learn that I had drawn a very early number in the lottery: Number eight!

That evening, with my Macintosh computer perched on the narrow table in the booth of the café, Jaron and I met and brainstormed. Jaron submitted his work before the deadline, resulting in the article being published in the September 1984 issue of *Scientific American*. That night, as we discussed the article that he was working on, Jaron shared with me his vision of a much better computer interface. A more natural way to program and to use computer technology to work, socialize, have fun, learn, study, and explore the world (and the universe). Jaron had not yet popularized the phrase virtual reality, but he shared his basic vision for the technology. During that late-night discussion, the full impact that virtual reality technology would have on healthcare and medical research struck me. The effect that realization had on me was profound. It dramatically shifted my professional direction and propelled me to focus my full efforts on applying VR technology to clinical care. I mentally committed to do my best to help move the field forward.



As I write this introduction now almost forty years after that conversation, it is exhilarating to see the progress that has been made. Virtual reality technology is used throughout the world in a wide variety of ways: to support medical education and skill training, to improve clinical assessments and interventions, and to promote personal health and wellness. Numerous VR clinical systems have been developed and validated at academic research centers. An impressive body of research literature has been published that demonstrates the efficacy and therapeutic value of virtual reality-based tools in medicine, providing the proper context for further advances.

We know from the many decades of clinical research that VR technology can provide breakthrough solutions that address the most challenging problems in healthcare: Ranging from mood disorders such as anxiety, depression, and post-traumatic stress disorder (PTSD), addiction, autism, cognitive aging, stroke recovery, and physical rehabilitation, to name just a few. VR/AR technology, when combined with machine learning and biosensing technology, can be used to improve clinical measurements and assessments by making them more objective and functional. VR and AR systems improve clinical training such as surgical skill training and procedure planning by applying simulation-based learning principles. Previously, the cost of VR technology was a barrier to acceptance outside of the university and military environments. Now, the reduced cost of hardware and increased availability of virtual reality applications make clinical VR practical for everyday use.

My enthusiasm for the use of VR in healthcare hasn't wavered. Looking toward the near future, it is clear that virtual reality, augmented reality, machine learning, and biosensing technology will be used as the foundation for the next generation of clinical and telemedicine systems. This confluence of technology will reduce the cost of healthcare delivery, improve clinical efficiency, address previously intractable clinical problems, as well help our clinical networks reach previously underserved populations. The VR clinical ecosystem has grown exponentially, in large part due to the pioneers who contributed to this book. The momentum is accelerating, and the chapters that follow illuminate the path forward. This is an exciting and transitional time for our field.



- Walter Greenleaf

My background as a technology founder working in the startup space made for a logical transition into reporting on the intersection of health and technology, which resulted in my writing a profile on Dr. Walter Greenleaf for *Neo.Life*. After researching the VR healthcare landscape and interviewing or hearing the majority of this book's contributors speak at conferences, I realized that no one person's imprint extended as far and wide as Walter's when it came to nurturing, protecting, and promoting a technology. Having had the opportunity to report on the history, challenges, and future of VR transforming medicine through Walter's lens has been a privilege and honor. I believe Aaron Wisniewski, CEO of OVR, said it best: "In the VR solar system, Walter's the sun. He gives light to all of us and keeps us elegantly orbiting and traveling in the right direction." This book offers the reader a journey through the evolving medical VR galaxy.

In the early nineties, I experienced the beginnings of what we refer to today as the World Wide Web. Back then, I'd spend hours trying to convince software executives that the Internet would change our lives radically. There was a combustive excitement about the "global village" amongst a small group of us who knew what was coming. Not since the advent of the Internet have I been so excited about a platform's ability to transform every aspect of our lives.

Indeed, Facebook just announced plans to create 10,000 new jobs across the EU to develop what it calls the *metaverse*, an online world where people can play, work and communicate in a virtual environment, often using VR headsets. The concept isn't new. It was coined by science fiction author Neal Stephenson in his 1992 novel *Snow Crash*. However, the vision is growing. While the metaverse is evolving, it holds new potential in healthcare, thanks to many pioneers in the following pages. Maybe, like me, you believe the metaverse is the future of the Internet. Just as we've seen clunky cellphones evolve into smartphones, I'm certain that VR will bring a renaissance to medicine by integrating technologies, data, and countless innovations. Just to put things in perspective, on New Year's Day in 1994, there were an estimated six hundred and twenty-three websites. I liken the authors in this book to the founders of those first websites, catalyzing change within the global village of medicine.

After experiencing virtual reality (VR) for the first time, I was hooked. As a writer, it's challenging to explain what happens when an immersive experience grabs your complete attention, transporting you cognitively to another time, place, body, situation or location, to a reader who has not had a VR experience and thus has no context. VR creators are extending sensory engagement to our other senses, like touch and smell, which are deepening our immersive experience. VR, by its nature, is all-encompassing, and one of its advantages is that it can reach people in all sorts of ways, evoking emotional responses and incorporating social elements. I believe VR will be one of the most transformative technologies over this decade. The rollout of 5G technology will have a significant impact in this space, especially as cloud services allow us to consume content just like we currently consume music and movies.

In VR, we can shrink students down to a cellular level to study anatomy and expand them to soar above the planets to better understand the universe, which gives me hope that they'll be better equipped to solve tomorrow's challenges. Just as wearable technology has become more commonplace, the use of neural implants and non-invasive brain-computer interfaces (BCIs) will drive innovation and help so many with extreme disabilities. In the future, these devices could not just restore lost function, but also enhance cognitive function. Since the widespread adoption of such technology is still in its nascent stage, this brings concerns over privacy, security, and trust. Fortunately, this community is committed to protecting and safeguarding the population they serve by creating a safe and transparent ecosystem.



- LaVonne Roberts

This book is for healthcare professionals, academics, technologists, designers, research scientists, and anyone who wants to better understand the benefits of healthcare applications for VR. The following chapters provide a comprehensive overview of how VR technologies are paving the way for groundbreaking solutions. The pandemic dramatically accelerated the adoption of digital healthcare. Consequently, we are witnessing an exciting period of rapid growth in virtual reality, augmented reality, and mixed reality technologies, collectively known as XR (extended reality). Systems that leverage VR technology are having an impact in several key sectors of healthcare. They are currently in use to improve clinical skill training, to provide objective assessments in behavioral and physical health, to optimize clinical interventions, to facilitate clinical adherence, and to make it easier for individuals to focus on preventive health and optimize wellness programs.

Based on current statistics, there will soon be a shortage of healthcare professionals globally. The World Health Organization forecasts a shortfall of 12.9 million healthcare workers by 2035. To address this concern, VR systems are being used as a telemedicine platform to extend the reach of the clinician and provide clinical care to previously underserved areas. An additional key driver to VR adoption in healthcare is the acute need to reduce healthcare costs. Recent advances in the graphical power of VR systems provide dramatically increased levels of immersion and “*presence*” in VR environments, opening new possibilities for the cost-effective use of VR in several key sectors of medicine: including neurology, psychiatry, clinical psychology, and neurorehabilitation. Keeping the fundamental forces that are shaping our healthcare ecosystem in mind, it is heartening to know that the VR systems and technologies that are described in this book are providing significant contributions to improving healthcare. Listed below are a few examples:

### **Diagnostics**

VR will enable physicians to diagnose diseases remotely by real-time monitoring of physiological parameters, data driven reporting, and the interaction between patient and physician, providing more individualized care.

### **Medical Training**

VR technology is being used to improve all aspects of medical training: Clinical and skill training, equipment and tool usage, and team training (e.g., emergency department and surgical teams). Further, it can teach empathy and improved understanding of patients and their experiences.

VR surgical training offers a safe learning environment for medical students and surgeons to acquire the necessary skills they need in a risk-free virtual situation. Using virtual reality, students can visualize the human body's interior, unveiling otherwise inaccessible areas. All types of healthcare professionals can learn in virtual environments by simulating difficult and dangerous scenarios that are impossible or too expensive to recreate in real life. VR combined with analytics can track and measure quantifiable data, offering organizations' workforces better preparedness.

### **Treating Mental Health Issues**

Virtual worlds allow the patient to visit places they can't ordinarily access. Simulations of psychologically challenging scenarios like flying, shopping in crowds, or climbing heights, enable therapists to guide patients. Traumatic events behind PTSD can be recreated in VR, allowing therapists to work closely with patients in a safe environment. Situations once impossible to recreate, like the trauma experienced on the battlefield, are now possible.

### **Pain Management**

VR has been proven to reduce pain, resulting in a reduction in recovery time. Applications help alleviate pain by effectively diverting a patient's attention, minimizing potentially addictive opioids and reducing healthcare costs.

## **Physical Therapy and Rehabilitation**

VR is especially conducive to advancing physical therapy because it provides real-time measurable data to clinicians and patients, motivating users to strive for better results. One of the many advantages of physical therapy in a virtual environment is that it can be customized to age groups, from pediatric patients to older populations. Additionally, it distracts a patient's attention from their discomfort by immersing them in an engaging alternative reality that motivates and encourages them to complete rehabilitative activities.

Clinicians are using a gamified approach to help patients rehabilitate after a stroke or brain injury, offering access to exercises that help restore motor skills. Algorithms within stroke rehabilitation software can monitor patient performance, adjusting the difficulty automatically to ensure progress while providing therapists vital data to better monitor treatment. Rehabilitation can be remote and on-demand, significantly minimizing treatment and transportation costs.

## **Surgical Planning and Preparedness**

VR can transport clinicians inside the human body to view areas that would otherwise be impossible to reach. VR allows patients to virtually understand their surgical plan, using 360-degree VR reconstruction of their anatomy and pathology, resulting in higher patient satisfaction.

## **Enhancing the Patient Experience**

Using VR, doctors can better explain how they will perform operations, and patients can better understand what to expect and how to improve their recovery. Virtual applications can show patients how certain lifestyle practices and damaging substances can affect their future health.

We are at the precipice of a technological revolution radically changing medical training and care systems. COVID-19 proved that healthcare can solve big challenges quickly. It also helped to advance a new wave of industry innovation.

Are you ready to take on this journey with us?