

4. Why I Love VR (About the Basics)

Recall that this book has two kinds of chapters. One kind tells a story and the other explores topics in virtual reality. This is the first of the second kind of chapter. Here I will introduce some general ideas about VR. The other “about” chapters to come will examine different aspects of a VR system, such as visual displays.

The Mirror Reveals

Even though it's finally becoming more widely accessible, a lot of the joy in VR remains in just thinking about it.

One way to think about VR is through surreal thought experiments. Imagine the universe with a person-shaped cavity excised from it. What can we say about the inward-facing surface that surrounds the cavity?

Fourth VR Definition: The substitution of the interface between a person and the physical environment with an interface to a simulated environment.

You can think of an ideal virtual reality setup as a sensorimotor mirror; an inversion of the human body, if you like.

In order for the visual aspect of VR to work, for example, you have to calculate what your eyes should see in the virtual world as you look around. Your eyes wander and the VR computer must constantly, and as instantly as possible, calculate whatever graphic images they would see were the virtual world real. When you turn to look to the right, the virtual world must swivel to the left in compensation, to create the illusion that it is stationary, outside of you and independent.

Back in the early days I used to luxuriate when I described this most basic principle of VR to people who had never heard of it. People just flipped out when they first got it!

Wherever the human body has a sensor, like an eye or an ear, a VR system must present a stimulus to that body part to create an illusory world. The eye needs visual display, for instance, and the ear needs an audio speaker. But unlike prior media devices, every component of VR must function in tight reflection of the motion of the human body.

Fifth VR Definition: A mirror image of a person's sensory and motor organs, or if you like, an inversion of a person.

Or, to make it more concrete:

Sixth VR Definition: An ever growing set of gadgets that work together and match up with human sensory or motor organs. Goggles, gloves, floors that scroll, so you can feel like you're walking far in the virtual world even though you remain in the same physical spot; the list will never end.

The ultimate VR system would include enough displays, actuators, sensors, and other devices to allow a person to experience, well, anything. Become *any* animal or alien, in *any* environment, doing *anything*, with effectively perfect realism.

Words like "any" show up a lot in VR definitions, but after working

with VR, most researchers learn to be suspicious whenever “any” is uttered. What’s wrong with this innocent-seeming little word?

My position is that in a given year, no matter how far we project into the future, the best possible VR system will never achieve complete coverage of all the human senses or measurement of everything there is to be measured from a person. Whatever VR is, it’s always chasing toward an ultimate destination that probably can’t ever be reached. Not everyone agrees with me about that.

Some VR freaks think that VR will eventually become “better” than the human nervous system, so that it wouldn’t make sense to try to improve it anymore. It would then be as good as people could ever appreciate.

I don’t see things that way. One reason is that the human nervous system benefits from hundreds of millions of years of evolution and can tune itself to the quantum limit of reality in special cases already. The retina can respond to a single photon, for instance. When we think technology can surpass our bodies in a comprehensive way, we are forgetting what we know about our bodies and physical reality. The universe doesn’t have infinitely fine grains, and the body is already tuned in as finely as anything can ever be, when it needs to be.

There will always be circumstances in which an illusion rendered by a layer of media technology, no matter how refined, will be revealed to be a little clumsy in comparison to unmediated reality. The forgery will be a little coarser and slower; a trace less graceful.*

But that’s not even the best reason to think that our simulations will not surpass our bodies.

When confronted with high-quality VR, we become more discriminating. VR trains us to perceive better, until that latest fancy VR setup

* Arguments about this point of view were common—voracious, actually—in the 1980s. The counter was and remains that we will eventually gain mastery over physical reality in every detail, through a hypothetical, ultimate nanotechnology, so that there will no longer be a distinction between virtual and physical reality. For instance, what about a hypothetical future of augmented human anatomy? If we come to see the world better through enhanced sensory organs, would we not also be able to feed those same organs directly with data from a simulation? These arguments go round and round, but I still think the brain will just get better and better at detecting forgeries. Remember, we can’t outrun the *interactivity* of reality. If we someday enhance our vision with super-high-resolution artificial retinas that can see many more colors—even then, the key to perception will be the interactivity, the probing. Even then, VR won’t look as real as what we can see of physicality through our new eyes, provided we allow those eyes to roam true.

doesn't seem so high-quality anymore. The whole point of advancing VR is to make VR always obsolete.

Through VR, we learn to sense what makes physical reality real. We learn to perform new probing experiments with our bodies and our thoughts, moment to moment, mostly unconsciously. Encountering top-quality VR refines our ability to discern and enjoy physicality. This is a theme I will return to many times.

Our brains are not stuck in place; they're remarkably plastic and adaptive. We are not fixed targets, but creative processes. If time machines are ever invented, then it would become possible to snatch someone from the present and put that person in a future, highly sophisticated VR setup. And that person would be fooled. Similarly, if we could grab people from the past and put them in our present-day VR systems, *they* would be fooled.

To paraphrase Abraham Lincoln: You can fool some of the people with the VR of their own time, and all of the people with VR from future times, but you can't fool all of the people with the VR of their own time.

The reason is that human cognition is in motion and will generally outrace progress in VR.

Seventh VR Definition: A coarser, simulated reality fosters appreciation of the depth of physical reality in comparison. As VR progresses in the future, human perception will be nurtured by it and will learn to find ever more depth in physical reality.

Because of future progress in VR technology, we humans will become ever better natural detectives, learning new tricks to distinguish illusion from reality.

Both today's natural retinas and tomorrow's artificial ones will harbor flaws and illusions, for that will always be true for all transducers. The brain will constantly twiddle and test, and learn to see around those illusions. The unceasing flow of tiny learning forces—pressed finger against pliant material, sensor cell in the skin exciting a neuron that signals the brain as the pressure reflects—this flow is the blood of perception.

Verb Not Noun

Virtual reality researchers prefer verbs to nouns when it comes to describing how people interact with reality. The boundary between a person and the rest of the universe is more like a game of strategy than like a movie.

The body and the brain are constantly probing and testing reality. Reality is what pushes back. From the brain's point of view, reality is the expectation of what the next moment will be like, but that expectation must constantly be adjusted.

A sense of cognitive momentum, of moment-to-moment anticipation, becomes palpable in VR.*

So how can we simulate an alternate reality for a person? VR is not about simulating reality, really, but about stimulating neural expectations.

Eighth VR Definition: Technology that rallies the brain to fill in the blanks and cover over the mistakes of a simulator, in order to make a simulated reality seem better than it ought to.

Actionable definitions of VR are always about the process of approaching an ideal rather than achieving it. Approach, rather than arrival, is what makes science realistic, after all. (If that way of understanding science isn't clear to you, please read this footnote.)†

* It's been suggested that it's the same thing as the "chi" in "tai chi," but I don't know enough to comment on that.

† Here is an example showing how science is about approach instead of arrival: The twentieth century brought us two theories of physics, quantum field theory and general relativity, that are so good that no one has yet devised an experiment that exposes an inaccuracy in either of them. And yet they disagree with each other when it comes to some extreme situations related to the universe as a whole, or to black holes.

So we know physics isn't "done." That doesn't mean that progress hasn't been authentic: Relativity gives our GPS sensors accuracy and quantum field theory allows us to stuff the resulting data into fiber optic cables under the sea. We couldn't do any of that without the theories. And yet there's obviously more to be discovered.

Science isn't about the certainty of coming to a final conclusion, and this can make it emotionally unsatisfying. The mind thinks thoughts, so it wants reality to be like a thought, to stake out a position, to be Platonic. But science is only about making gradual progress, holding a candle in a great darkness.

Minds can get stubborn about thoughts, and expect reality to be a certain way and have that be the end of it. Alas, eternal reality hasn't been revealed to us totally and instantly.

There's a grandeur in the gradual way science progresses. It takes a while to get used to it, but once you see it, the incremental ascent of science becomes a thing of beauty and a foundation for trust.

I appreciate the infinite elusiveness of a perfected, completed form of VR in the light of this sensibility. Reality can never be fully known, and neither can virtual reality.

Ninth VR Definition: The investigation of the sensorimotor loop that connects people with their world and the ways it can be tweaked through engineering. The investigation has no end, since people change under investigation.

A Vice to Avoid

An obstacle to understanding is that popular metaphors for the nervous system come from commonplace gadgets that operate on principles that are alien to the brain. It is quite common, for instance, to think of eyes as being like cameras, ears like microphones, and brains like computers. We imagine ourselves as USB Mr. Potato Heads.

A better metaphor: The head is a spy submarine, sent out into the world to perform a multitude of experimental missions to try to discern what's

Since science isn't absolutely done, people can feel emotionally cheated by science. It's like when we want a perfect king, and yet all we can ever really get is an imperfect politician. It sucks.

I feel these emotions too. Sometimes I wish science could be perfect. But you just have to get used to the way things work in this reality of ours. It's a miracle, an amazement, a stunning blessing, that we can make progress at all. We can understand more than we used to. Even so, it sucks that we are still not omniscient.

The imperfection of our understanding can make us lash out at science the way we lash out at our politicians. Climate change deniers and antivaccine people argue that if science isn't done, then *nothing* has been settled. Sometimes, certain AI people can believe that just because we've learned a few things about how brains work, we must already understand *everything* crucial about how brains work.

I feel the emotions behind these exaggerations, but what makes science worth trusting is that it doesn't promise everything. Only charlatans promise everything. Science has settled *some* issues. Boy, is it hard to accept *some* when what you really want is *everything*.

When you lash out at decent but imperfect politicians, you only get worse politicians who pretend to be kings. When you lash out at incomplete but valid science, you offer yourself up to con artists.

out there. A camera placed on a tripod typically takes a more accurate picture than one held by hand. The opposite is true for eyes.

If you immobilize your head in a vise, and to complete the picture, if you inactivate the muscles that move the eyes about in their sockets, you will have simulated putting your eyes on a tripod. For a moment you'll continue to see as before, though it might feel as if you're looking at a movie. Then something terrifying will happen. The world around you will fade to a sickly gray and then disappear.

Vision depends on continuous experimentation carried out by the nervous system, actualized in large part through the motion of the head and eyes. Look around you and notice what happens as you move your head in the smallest increments you can manage. Seriously, stop reading for a moment and just look around and notice how you see.*

Move your head absolutely as little as you can, and you will still see that edges of objects at different distances line up differently with each other in response to the motion. This is called "motion parallax" in the trade. It's a huge part of 3-D perception.

You will also see subtle changes in the lighting and texture of many things. Look at another person's skin and you will see that you are probing into the interior of the skin as your head moves. (The skin and eyes evolved together to make this work.) If you are looking at another person, you will see, if you pay close attention, an unfathomable variety of tiny head motion messages bouncing back and forth between you. There is a secret visual motion language between all people.

If you are not able to perceive these things, try going into VR for a while and then come out and try again.

Vision works by pursuing and noticing changes instead of constancies, and therefore a neural expectation exists of what is about to be seen. Your nervous system acts a little like a scientific community; it is voraciously curious, constantly testing out ideas about what's out there. A virtual reality system succeeds when it temporarily convinces the "community" to rally behind an alternate hypothesis. (If VR ever succeeds on a permanent basis, we will have entered into a new form of catastrophic political failure. The more we each become familiar with successful *temporary* VR experiences, however, the less vulnerable we become to this bleak fate.)

* If you're blind, the principle works equally for hearing.

Once the nervous system has been given enough cues to treat the virtual world as the world on which to base expectations, VR can start to feel real, realer than it ought to, in a way, which is a dead giveaway.

The nervous system is holistic, so it chooses one external world at a time to believe in. A virtual reality system's task is to sway the nervous system over a threshold so that the brain believes in the virtual world instead of the physical one for a while.

Tenth VR Definition: Reality, from a cognitive point of view, is the brain's expectation of the next moment.

In virtual reality, the brain has been persuaded to expect virtual stuff instead of real stuff for a while.

The Technology of Noticing Oneself

VR is a hard topic to explain because it's hard to contain. It directly connects to every other discipline. I've had visiting appointments in departments of math, medicine, physics, journalism, art, cognitive science, government, business, cinema, and sure, computer science, all because of my work in this one discipline of VR.

Eleventh VR Definition: VR is the most centrally situated discipline.

For me, VR's greatest value is as a palate cleanser.

Everyone becomes used to the most basic experiences of life and our world, and we take them for granted. Once your nervous system adapts to a virtual world, however, and then you come back, you have a chance to experience being born again in microcosm. The most ordinary surface, cheap wood or plain dirt, is bejeweled in infinite detail for a short while. To look into another's eyes is almost too intense.

Virtual reality was and remains a revelation. And it's not just the world external to you that is revealed anew. There's a moment that comes when

you notice that even when everything changes, you are still there, at the center, experiencing whatever is present.

After my hand got giant, it was natural to experiment with changing into animals, a splendid variety of creatures, or even into animate clouds. After you transform your body enough, you start to feel a most remarkable effect. Everything about you and your world can change, and yet you are still there.

This experience is so simple that it is hard to convey. In everyday life we become used to the miracle of being alive. It feels ordinary. We can start to feel as though the whole world, including us, is nothing but mechanism.

Mechanisms are modular. If the parts of a car are replaced one by one with the parts of a helicopter, then afterward you will end up with either a helicopter or an inert meld of junk, but not with a car.

In virtual reality you can similarly take away all the elements of experience piece by piece. You take away the room and replace it with Seattle. Then take away your body and replace it with a giant body. All the pieces are gone and yet there you are, still experiencing what is left. Therefore, you are different from a car or a helicopter.

Your center of experience persists even after the body changes and the rest of the world changes. Virtual reality peels away phenomena and reveals that consciousness remains and is real. Virtual reality is the technology that exposes you to yourself.

There's no guarantee that a tourist in VR will notice the most important sight. I did not notice this most basic aspect of what I was working on until I experienced bugs in VR, like the giant hand. I wish I knew what threshold of elements might bring other people to appreciate the simplest and most profound quality of the VR experience.

Twelfth VR Definition: VR is the technology of noticing
experience itself.

As technology changes everything, we here have a chance to discover that by pushing tech as far as possible we can rediscover something in ourselves that transcends technology.

VR is the most humanistic approach to information. It suggests an

inner-centered conception of life, and of computing, that is almost the opposite of what has become familiar to most people,* and that inversion has vast implications.

VR researchers have to acknowledge the reality of inner life, for without it virtual reality would be an absurd idea. A person's Facebook page can continue after death, but not the person's VR experience. Who is the VR experience for, if not for you?

VR lets you feel your consciousness in its pure form. There you are, the fixed point in a system where everything else can change.

From inside VR you can experience flying with friends, all of you transformed into glittering angels soaring above an alien planet encrusted with animate gold spires. Consider who is there, exactly, while you float above those golden spires.

Most technology reinforces the feeling that reality is just a sea of gadgets; your brain and your phone and the cloud computing service all merging into one superbrain. You talk to Siri or Cortana as if they were people.

VR is the technology that instead highlights the existence of your subjective experience. It proves you are real.

* This is one of those ideas that seems so obvious to some people that they find it tedious if I elaborate, while others find it puzzling. If it seems puzzling, you might sneak a peek at the sections about artificial intelligence later in the book, starting with "Birth of a Religion" on page 257.