The Metaverse: What's Now, What's Next

JESSE SCHELL

Lately, there's been an awful lot of talk about the Metaverse. This is something I've given a lot of thought, and I'd like to share some of that thinking with you.

My initial exposure to the world of virtual reality came in graduate school in the early nineties. Very soon after, I got a position at Disney R&D in the virtual reality studio there. Of course, it was 30 years ago, and commercial headsets weren't available. We had to make our own headsets. They were so heavy that we needed to create a special system of steel cables with this whole counterweight system to keep them from overly straining your neck. These headsets were used in a place called Disney Quest, a virtual reality theme park at Disney World in Florida that was open for about 20 years. The first VR experience we created was ALADDIN'S MAGIC CARPET RIDE,[1] and then we made CAVE-based things like the PIRATES OF THE CARIBBEAN EXPERIENCE.[2] I went on from this Disney Quest project to create online worlds. Disney's TOONTOWN ONLINE[3] was one of the first I worked on, and later, a Tinkerbell world called PIXIE HOLLOW.[4]

In 2002, I came to Carnegie Mellon's Entertainment Technology Center, where I started teaching classes on virtual reality. Over the years, I've watched students create more than a thousand different virtual worlds. Also, in 2002, I founded a company called Schell Games. In the 20+ years since then, we have created about 100 games and interactive experiences, many of them (around 20%) being VR and AR games. Immersive technologies, particularly VR, is a space that

1 ALADDIN'S MAGIC CARPET RIDE (Disney Quest, 1998, O: Disney VR Studio).

2 PIRATES OF THE CARIBBEAN EXPERIENCE: BATTLE FOR BUCCANEER GOLD (Disney Quest, 2000, O: Disney Studios).

3 TOONTOWN ONLINE (Disney Interactive, 2003, O: Disney Interactive).

4 PIXIE HOLLOW (Disney Online Studios, 2008, O: Disney Online Studios).

we are very excited about, and we're also excited about exploring its relation to the online world space.

How does all that relate to the Metaverse? Different people mean different things when they talk about the Metaverse. The four most common technologies that people discuss in this context are virtual reality, augmented reality, online worlds, and blockchain. There is an observation that these four things are potentially converging. There's a lot of confusion around just these four technologies alone, and even more confusion about combining them together into something new. People have different visions of exactly what will happen, but something is coming.

I will structure my analysis by talking about the different myths of the Metaverse.

MYTH #1: VR IS A FAD

The first myth I want to address is the idea that VR is a fad. I hear this a lot. People say: *Oh, well, that was a thing. Someone tried it. It didn't really work, did it?* Or: *Oh yeah, it's kind of happening now, but it's going to go away soon.* It's the feeling of: *I don't know if it's persistent.* And I'm telling you: VR is here to stay. It is going to be part of the digital landscape permanently from now on. Some people say: *Well, how can that be? If technologies are not a huge hit as soon as they come out, they're not going to succeed, right?*

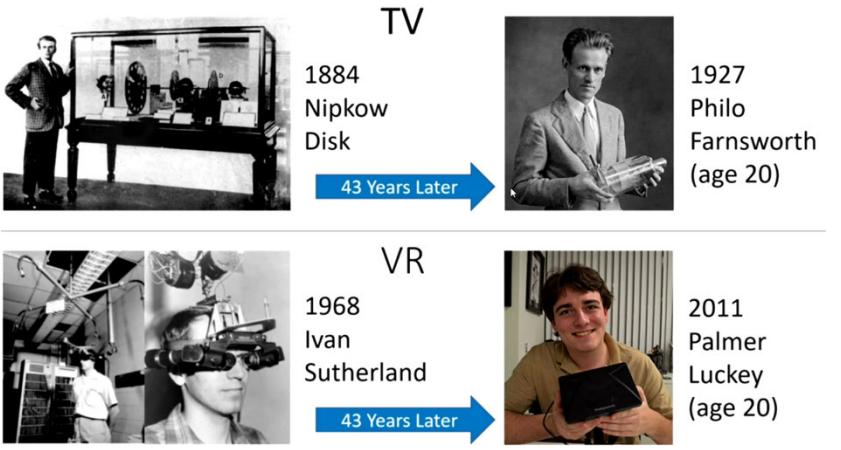
But that isn't how technology works. You can look at the development of television as a good example. When did the television first appear? Most people would say: Probably mid-forties, late 1940s, something like that. And that's not true. The first television system was created in 1884.[5] It didn't work right, but it was a system able to send images at a distance through a wire. It took a lot of development to make television actually work. Can you imagine what it was like to be someone working on television in the 1890s? In 1900? In 1910? In 1920? These were times when it wasn't at all clear that this technology was feasible and going to move forward. But eventually, it did. Forty-three years later, there was a breakthrough from a young punk named Philo Farnsworth, who was out plowing

5 Cf. Nipkow, Paul: "German Patent Specification No. 30105 Relating to the Invention of the Perforated Scanning Disc," *Science Museum Group*, no date [1884], https://collection.sciencemuseumgroup.org.uk/objects/co34827/copy-of-german-patent-perforated-scanning-disc-patent

a field.[6] And as he moved the lawn mower back and forth, it occurred to him that electron beams could be manipulated with magnets in a way that could potentially draw a picture. And this could be a better way to render images than they had been using. It was the breakthrough that television needed. It brought it into the modern age. However, it took some time.

If you look at VR, you can see similarities. The first VR system was Ivan Sutherland's, which appeared in 1968. Now, I'm going to give you a super eerie parallel. Exactly 43 years later, a similarly young punk named Palmer Luckey shows up, and he says: *I know we've got a lot of problems, and VR hasn't quite hit the mass market, but we could if we made the lenses plastic, and did color correction, and we made some changes with OLEDs. Then we could make a system that would work much better.* And this was the breakthrough—the Oculus.[7]

Figure 1: The Eerily Parallel Development of TV and VR

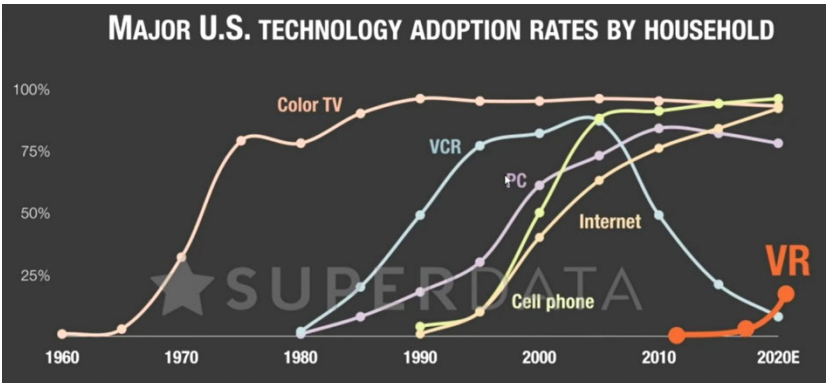


Source: J. Schell, "The Metaverse. What's Now, What's Next," presented at the 13th Clash of Realities Conference, 2022

6 Cf. Eschner, Kat: "The Farmboy Who Invented Television," *Smithsonian Magazine*, August 28, 2017, https://www.smithsonianmag.com/smart-news/farmboy-who-invented-television-while-plowing-180964607/

7 Cf. Clark, Taylor: "How Palmer Luckey Created the Oculus Rift," *Smithsonian Magazine*, November 2014, https://www.smithsonianmag.com/innovation/how-palmer-luckey-created-oculus-rift-180953049/

Figure 2: Major U.S. Technology Adoption Rates by Household



Source: Superdata. Micheal Felton, *The New York Times*; Pew Research Center; Gallup; U.S. Census

So, VR wasn't an overnight thing. It is a technology that developed slowly. It's still developing right now. The adoption curve is gradually increasing. And it's worth considering the adoption curves of new technologies. Television, VCR, the PC, Internet: none of these things were embraced immediately. Not even cell phones and smartphones. They all had a slow ramp-up and then exponential growth. We are seeing some of the same things with VR. Over the last five years, we've watched the number of headsets in the marketplace double each year—from one million to two million to four million to eight million. As of 2022, we have at least sixteen million.[8] How long will that doubling go for? I don't know, but we're definitely seeing an exponential growth rate right now.

So, what does state-of-the-art VR look like at the present? It doesn't look like putting VR on a phone, PC, or console. These are not places and platforms that were designed for VR. We tried to take existing systems and tack VR on as a sort of parasite that lives in a system that wasn't designed for it. These have been short-term solutions, but a longer-term solution is an all-in-one system. An example

8 Cf. N.N., "Volume of the VR Headsets Market Worldwide from 2018 to 2028," *Statista Market Insights*, August 8, 2023, https://www.statista.com/forecasts/1331896/vr-headset-sales-volume-worldwide

right now is the Oculus Quest or Meta Quest system. It has been shockingly successful. Fifteen million of these were estimated to have been sold as of 2022.[9] That's more than the current generation of Xbox. People often don't realize how successful this is becoming. So, what has made this particular system so much more successful than the others? It seems to be an interesting combination of things. The price is very affordable. It's about the price of a regular game console, and very importantly: there are no wires coming out of the headset and no wires coming to the hand controllers. This has been surprisingly significant. It seems to have to do with people feeling more comfortable in their bodies and the ability to move this system around easily because people use their headsets in different places.

Not only is having a good headset important, but the hand controllers are important, too. Many people talk about these hand controllers as if they are temporary: *Oh, we just have these for now. Soon, we're going to want empty-hand interactions with VR.* I don't think that's right. I think the touch-ability and the tactile response of the hand controllers are going to make them a long-term part of these kinds of interactions. You can get by with empty-hand interactions where you only have to interact a little bit, and you don't have to be precise. But it's not the way in which people are going to want to interact. I believe, in the long term, we will see that hand controllers are a part of VR.

MYTH #2: VR IS TECHNOLOGY FOR THE EYES

This brings me to the second myth about VR. A lot of people think of VR as a technology for the eyes, and certainly, the eyes are involved. But that is not what VR is— just some fancy 3D glasses. Back a little while ago, people said: *Oh, 3D TV, that's going to be the thing! Everybody is going to have a 3D TV,* and the TV industry was very excited about it. But that's not what happened at all. 3D TV was a total flop because people don't care that much about 3D imagery. It's kind of nice and interesting, but particularly when it's in a rectangular frame, it has a lot of problems because it gets clipped on the edges. And it's not like 3D is something

9 Cf. N.N.: "AR/VR Headset Shipments Grew Dramatically in 2021," *International Data Corporation*, March 21, 2022, https://www.idc.com/getdoc.jsp?containerId=prUS48969722

new. The first commercial 3D imagery systems come from the 1840s.[10] The technology is not that complicated: two side-by-side pictures. If we really liked 3D so much, we would still be using this 170-year-old technology. But we don't. Your family photos aren't in 3D; your home movies aren't in 3D. Nintendo made the 3DS, and then they backed off. They went to the Switch and said: *Now forget that 3D stuff.* Phones would be in 3D, and they certainly could be. But it's not 3D itself that's very important. What's essential about VR is that it gives a sense of presence—the feeling that you are in another place, that the virtual things around you are substantial and real, and you can interact with them spatially.[11]

This is a very special feeling because it seems that there's something deep in your brain that decides what around you is real and what is not. No one watching a television show ever thinks: *Wait, are these things really in the room with me?* In VR and AR experiences, intellectually, you know it's not real, but you still see moments of confusion. Maybe you're trying to solve a puzzle in VR. You're thinking hard and reach your hand out because there's a virtual table. You'll go to lean on the table, and then you realize it's not there now. You knew there was no table, but your body forgot because your body was buying into the illusion of presence. That is the heart of what makes VR powerful. You do have your body in there. So often, as a design principle for VR, we ask, *how is this about my body?*

Another very real and related part of presence is social presence—the feeling of being in a room with other people who are spatially present around you. There's a nucleus in your brain that is all about when something enters your personal space. You cannot feel that when you're just looking at a screen.[12] But when you're in the real world or in VR, you can feel presence. Entering your personal space and social experiences will be key things that make VR continue to grow.

We often talk about the magical number of ten million. When there are less than ten million of something in the world, probably none of your friends have

10 Cf. Wheatstone, Charles: "Contributions to the Physiology of Vision. Part the First. On Some Remarkable and Hitherto Unobserved Phenomena of Binocular Vision," *Philosophical Transactions of the Royal Society of London* 128, (December 1838), pp. 371-394, https://doi.org/10.1098/rstl.1838.0019

11 For a discussion of presence in VR see e.g., Slater, Mel: "Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments," *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, no. 1535 (December 12, 2009), pp. 3549-57, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781884/

12 Cf. Holt, Daphne J. et al.: "Neural Correlates of Personal Space Intrusion," *The Journal of Neuroscience* 34, no. 12 (March 19, 2014), pp. 4123-413434, https://www.jneurosci.org/content/34/12/4123

one of them. When there are more than ten million of something in the world, probably at least one of your friends will have one. When a technology crosses over into more than ten million users, social effects accelerate because people start to get into the technology not so much for its own sake but for their social relationships.[13] *Hey, my friends are doing this. Maybe I should do it too.* And we're seeing this happen with VR right now. There's the expectation that we're going to see more acceleration of this because the social experience of meeting up with other people in a virtual space is a powerful one.

MYTH #3: THE METAVERSE IS ONE CONTINUOUS WORLD

Is that what the Metaverse is? Is it a big virtual world with a lot of people in it? There are certainly a lot of people who have proposed this. In fact, it's in the word Metaverse. The term was coined in the novel *Snow Crash*,[14] which envisioned a large, continuous virtual world. That was how virtual reality worked. You would go into this world and interact with other people in a kind of parallel to our physical world. *Ready Player One* painted a similar picture.[15] People get very excited about this picture—the idea of a world parallel to our own. And there's our third myth: that the Metaverse is one continuous world. It's just like the idea of *Toontown*—that all the cartoon characters live in one place. It's a very natural fantasy, but it's only a fantasy. The Metaverse does not want to be one continuous world, and it will not be.

We've been making video games for quite some time. If joining them all together into one continuous world was a good idea, we would have done it by now. But there's no real point. Worlds are powerful because they have boundaries. Good fences make good neighbors, and good boundaries make good worlds. And those strong boundaries are what define the worlds. Connecting them all together in a way that makes them one continuous space is not helpful. It's not good for them.

Many people point to ROBLOX as a potential precursor to the Metaverse because it is a big space with millions of people participating.[16] It's got all these different things in it. Well, it's not a continuous space. It's just a collection of

13 See e.g., Gladwell, Malcolm: *The Tipping Point*: *How Little Things Can Make a Big Difference*, New York, NY: Little, Brown and Company 2000.

14 Stephenson, Neal: *Snow Crash*, New York, NY: Bantam Books 1992.

15 Cline, Ernest: *Ready Player One*, New York, NY: Crown Publishers 2011.

16 ROBLOX (Roblox Corporation, 2006, O: Roblox Corporation).

small, disconnected, gated pocket worlds. People don't want to interact with a million other people at once. That's just not how it is. In the early days of online worlds, that's kind of what they were like. You look at EVERQUEST and WORLD OF WARCRAFT: they were these big continuous spaces, and there were hundreds of thousands of people in there. Have you noticed that those worlds aren't trendy anymore? If we look at some hot online games where people interact now, they're not interacting with thousands of people simultaneously. Look at the number of people players interact with simultaneously—COUNTERSTRIKE: ten;[17] LEAGUE OF LEGENDS: ten;[18] AMONG US just moved from ten to fifteen.[19] APEX LEGENDS: six,[20] PLAYERUNKNOWN'S BATTLEGROUNDS, and FORTNITE: 100.[21] Even ROBLOX has a limit of 100 people in one of their pocket worlds. And we top it off with CALL OF DUTY: you can theoretically get up to 150 people in CALL OF DUTY: WARZONE.[22]

This is the scale at which people want to interact because this is a very human scale. And if this number seems familiar, capping out at 150: you might have heard of Dunbar's number.[23] This is a study that shows that human societies tend to clump into groups of 150. We seem to be able to maintain a social network of about 150 people before our worlds break down. So historically, there's the belief that that's about how big villages were in ancient times. We can see it in organizations all the time: when they cross the boundary of 150, they start to split into two. The Metaverse will not form around technology or technological ideas. It will form around humans and human behavior and the way that human beings interact. So, the Metaverse is not going to be one continuous space. There will be lots of different pocket worlds where people interact the way they want when they want with whom they want.

You might say: *But a big, beautiful, continuous space—that's great. I love a big continuous space.* No, you really don't, because if you did, you wouldn't fly. You would get on the road and travel continuously across this space and enjoy the continuity of the space. But you don't want that. You'd teleport if you could, but

17 COUNTERSTRIKE:GO (Valve Corporation, 2012, O: Hidden Path Entertainment).

18 LEAGUE OF LEGENDS (Riot Games, 2009, O: Riot Games).

19 AMONG US (InnerSloth, 2018, O: InnerSloth).

20 APEX LEGENDS (Electronic Arts, 2019, O: Respawn Entertainment).

21 PLAYERUNKNOWN'S BATTLEGROUNDS (Krafton, 2017, O: PUBG Studios), FORTNITE (Epic Games, 2017, O: Epic Games).

22 CALL OF DUTY: WARZONE (Activision, 2020, O: Infinity Ward).

23 See Dunbar, Robin: "Neocortex Size as a Constraint on Group Size in Primates," *Journal of Human Evolution* 22, no. 6 (June 1992), pp. 469-493, https://doi.org/10.1016/0047-2484(92)90081-J

you can't. So instead, you do the next best thing, which is to make yourself terribly uncomfortable for a short period of time so that you don't have to deal with the geography between here and there because geography is just a lot of stuff that's in the way of where you want to be. And you drive. You have to put up with this and have to actually traverse continuous terrain. But that's not how the mind works. The mind doesn't move continuously. The mind jumps around. That's why films cut. Because the mind jumps around just as film cuts from place to place to place.

That's what we want with our virtual worlds. We want to jump: I'm going to go to this world. When I'm done with that, I'm going to go to this one. And that's how the Internet works. You can't make an accurate map of the Internet because it doesn't make any sense. The Internet is not a continuous space. The Internet is more like an index to the things that you care about. You can jump to what you want when you want to jump to it. If we're going to have anything that's at all like a Metaverse, that's what it's going to be—lots of separate worlds with clear boundaries between them.

MYTH #4: NFTS LET YOU BRING OBJECTS ANYWHERE IN THE METAVERSE

You might be saying: that's why I need NFTs, right? Because then I can take my virtual objects to every one of these separate worlds in the Metaverse. And that's myth number four. Many people talk about this idea that NFTs will let you bring objects anywhere in the Metaverse. I'll buy a red hat, and I'm going to wear my red hat in every single place in the Metaverse. What a business opportunity! Well, it's a nice idea, but honestly, it's probably not going to work. Let's talk about why.

Suppose you get this awesome virtual item, "The Antlers of Undead Wrath." Who wouldn't want that and everything that it implies? And you want to bring this item everywhere. I'm going to use "The Antlers of Undead Wrath" in a soccer game, and I will use them in SKYRIM, and when I'm in my virtual school application. This item will always do whatever "The Antlers of Undead Wrath" do. Well, there are problems if you're going to actually try to implement this because these worlds are created by very different people. You're going to have expectations about what these antlers are, how they work, what they do, how you should wear them, etc. Anything that becomes an object has to work in many different worlds. This is incredibly technically difficult because different worlds will be set up very differently. Creating standards that work all the way across the Metaverse might be possible, but it would be very challenging because everyone would have to

conform to these standards. There may one day be something like that, but it better be worth it because this will be hard work.

Then you have the issue that these items are thematically inconsistent. If I'm trying to make a beautifully themed world, and you show up with a bunch of random objects like "The Antlers of Undead Wrath" that don't really fit the world, and then everyone does that, then everything is just a random hodgepodge. And people don't go to worlds for a random hodgepodge. People go to worlds because there's thematic consistency, a certain mood, a certain feeling, a certain place that they want to be fully embraced in. So, if I'm going to bring random objects everywhere, that's a challenge and a problem. Again, you could manage it, but it'll be complicated. Also, if you're talking about game worlds, that could spoil game balance. Say you get an object that is really powerful. You can fly everywhere now. Now you expect to fly everywhere in all the worlds. Well, what if, in my world, flying messes it up because it ruins the game balance? How is that supposed to work?

And then lastly, when I can take all the objects out of a world, that encourages me to leave, and the people who make these worlds don't want you to leave. They want you to stay. They want boundaries, not just to define a world but to keep you in so that you keep interacting with people here and so that this world is financially successful for them. So, there are financial disincentives to creating systems that encourage players and users to exit a world and go to other worlds. Now, is this manageable? Yes, it's manageable, but the truth is, almost anything you want to do with NFTs, you can do with just a server. You're just looking up who owns what object. This works for most virtual worlds as long as you can get meaningful authentication on the server. We've been doing this for a long time, and it continues to work.

Some people will say: *Well, wait a minute, the problem is that somebody owns that server, and then they control that, not me. I want to be the one who really owns the item, not someone who can shut down the server and make it all disappear.* Okay, that's true. When Disney decided to shut down the TOONTOWN server, all those virtual objects did disappear. I understand that concern on some level, but on another level, when worlds are successful, they are managed and maintained indefinitely. Ownership is what prevents the tragedy of the commons. So, will NFT objects be a part of this picture? Yes. Will they be the dominant part of the way people own virtual objects? I'm skeptical about that.

BUT WHAT ABOUT AUGMENTED REALITY?

So, we've talked about virtual reality. We've talked about online worlds. But you might be saying: *Hey, wait a minute, are you implying the whole Metaverse is virtual reality?* Because some people don't like virtual reality. They don't want to put on a headset. It messes up their hair, makes them a little nauseous, and sometimes it's isolating. So, they are not excited about VR. They are excited about augmented reality. They want a tiny, lightweight pair of glasses. They don't want to go to some virtual world. They want virtual items to come to them. They want augmented reality, but not the augmented reality we have now.

Augmented reality on phones or tablets is not great. It creates no sense of presence. It's like going to a concert and watching it through your camera while you record it. Pretty soon, you realize: *I'm not really here at the concert. I'm kind of watching television of what's happening.* And you'd rather be immersed in the actual concert. Space is one of the reasons why we haven't seen significant success in this kind of augmented reality so far. We need to put on some glasses and just naturally see objects in the world. There's real excitement there. Because the difference between VR and AR is the difference between here and there. VR is about taking you there, to some other place. A place that isn't where you actually are. AR is about staying in the place you're in but bringing virtual objects to you. Both are about presence, but VR is about presence in a place that doesn't exist, and AR is about presence in the place that you exist in right now. People get excited about this. We've heard many people and many pitches and much funding raised around the idea that AR headsets will soon replace the smartphone. I think that this is a myth. Will it happen some future day? It is possible, yes. But that is not soon. It's going to be far off.

So why? What is the problem that is going to stop our headsets from being worn everywhere? Well, headsets generally are too dark or ridiculous-looking. People are sensitive about their appearance and things that look kind of weird. They get nervous about wearing headsets in public. Maybe if they are getting lighter, it's going to look more normal, like a regular pair of glasses. The Google Glass came out several years ago. It is very close to a normal-looking pair of glasses. However, it flopped in a big way. This wasn't just a slight failure. It was a crushing failure, not because it was bad technology or that it was hard to use, or that it wasn't even useful. In many ways, Google Glass was remarkable. But it's gone now because people weren't comfortable with it. It was not socially acceptable to wear these out in the world.

We should think about why that is. It wasn't just because it looked a little weird. It had to do in a big way with the nature of privacy. About thirty years ago,

I heard a lot of talk from people saying: *Oh, very soon, computers will be able to transcribe speech into text. And once we do that, no more typing. Everyone will just talk to their computers, and you'll speak instead of typing.* Well, here we are. We have transcribed human speech into text, and it works well, kind of amazingly well. But we're still typing. Why? Well, for two reasons. One is the way our brains work. It's hard to compose while you're talking. And the other side of it is, if you're talking out loud, people can hear you. And very often, people want privacy about what they're communicating. So, one thing to discuss with any VR or AR headset is these black dots on the front of the headset. They are scary because anytime you're facing someone who's wearing a headset, you're staring into the lens of a camera. With Google Glass, they intentionally did not put a light there to tell you whether the camera was on because they wanted people not to think about that. Well, now you worry all the time: *Am I being watched? How about now? Are you recording what I'm doing right now? Is someone watching me at a distance? This is not comfortable.* Being surveilled is a creepy feeling, and it's something that we haven't figured out yet. Wearing this out in the world, in public places, is a problem.

Another problem worth talking about is the field of view. What we see through optical pass-through glasses is cut off at the bottom and cut off at the top. That breaks the illusion. The presence is shattered because we have this limited field of view. Some people think that the optical pass-through will have a full field of view very soon. And I don't think that's true. Let's look at the history of lenses quickly. We have the Nimrud lens that was invented 2700 years ago.[24] If you're wearing glasses, you're using one of these right now. It's pretty old technology. The Fresnel lens was created for lighthouses in 1823.[25] It is used in a number of different headsets and things. It's a good advance in some ways. And then we have holograms that can be used in a lens, invented maybe seven decades ago.[26] And these are great because they're light and thin, but they have terrible chromatic aberration. That's why you see all those rainbows: because the colors are being blown all over the place. Systems that use optical passthrough generally use quantum waveguides, a form of hologram.

24 Khan, Sameen Ahmed: "Medieval Arab Contributions to Optics," *DOMES* 25, no. 1 (Spring 2016), pp. 19-35, https://doi.org/10.1111/dome.12065

25 Baker, Joanne: "History: Beam Me Home," *Nature* 498 (June 27, 2013), pp. 430-431, https://doi.org/10.1038/498430a

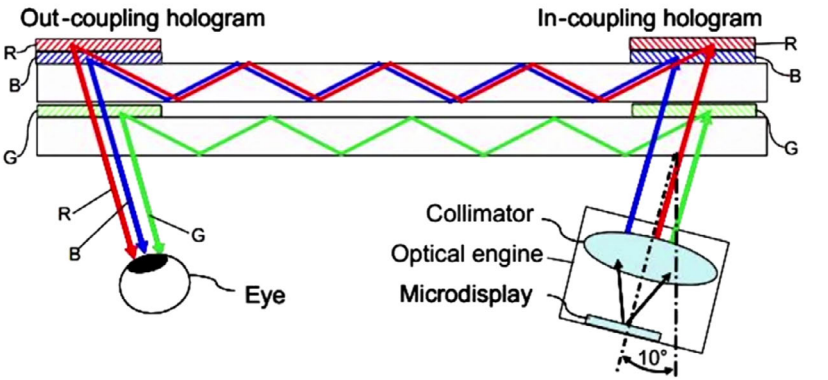
26 Gabor, Dennis: "Holography 1948-1971: Abstract of Nobel Lecture, 11 December 1971," *Europhysics News* 3, no. 3 (1972), pp. 8-9, https://www.europhysicsnews.org/articles/epn/abs/1972/03/epn19720303p8/epn19720303p8.html

Figure 3: History of Lenses

Source: J. Schell, "The Metaverse. What's Now, What's Next," presented at the 13th Clash of Realities Conference, 2022

Headsets with holograms work like this: You've got a display light coming in through a lens, and then it puts things into a hologram. You've got to have three holograms. One red, one green, and one blue because if you're trying to preserve color, you need one for each primary color. And then the image goes in, and amazingly, the image stays in the hologram, bounces along it, and then pops out where the eye is. It's amazing that this works at all. The problem is that the ingoing and outcome images must be the same size.

Figure 4: DigiLens Full-Color Volume Holographic Grating Waveguide Imaging Lightpath



Source: DigiLens

That's why you see these shapes in AR glasses, where this sort of flat channel goes along. But you want to make one that fills your whole field of view. You could do it, but it's not super comfortable. And so someday, maybe someone's going to invent an expanding waveguide. That's where the image can start out small and then gets bigger on the other side. No one's made that yet, and we're not sure how that could even be possible. So, this is an indefinite wait. In the meantime, video pass-through solutions like the Meta Quest 3 and Apple Vision Pro will be the primary method of delivering AR experiences.

Another thing we have to consider is software. Hardware is one thing, but the software mostly isn't ready yet either. You can float objects in space. That's fine. But who wants to float objects in space? You might as well be looking at the objects on a screen. Augmented reality is best when it *augments reality*. Show me what a watch looks like on my wrist. To do that, you need to be able to detect my wrist and then match the watch to it. It is challenging for computers to look at the world, and identify all the objects, all the places, and all the shapes. Identifying objects is hard. Arguably, half of the brain is spending its energy visually parsing the world and understanding what the objects are.[27] That's a lot to ask of a computer. We're making progress at room solving, but it's slow. So that's a real challenge if you're going to wander the world wearing your augmented reality headset and have the world itself be augmented.

All these challenges with augmented reality would cause some people to ask: *Is there a killer app for this, or is this like the Segway?* When the Segway was announced, they made a lot of big noise about it, like: *Oh, this is going to be the invention that changes the world. Whole cities are going to be designed around the Segway. It will replace bicycles. It will replace walking; it will replace cars. Everyone's going to get on a Segway all the time.* And that's not how it is. If you're a security guard or working in a warehouse, or you're taking an extended tour of a city, this is good technology. But it's not mass-market and in everybody's lives because it's only good for some things. For day-to-day life, the use of AR is a little unclear. Where is the application that will make people want to use it every day?

Now we know the killer app for VR: games. And so maybe it's the same thing for AR. But there's a problem with this because games are about escaping into fantasy worlds, and AR is about bringing virtual objects to you. Do you really want every video game you play to be set in your dingy living room? That isn't

27 Hagen, Susan: "The Mind's Eye," *Rochester Review* 74, no. 4 (March-April 2012), pp. 32-37, https://www.rochester.edu/pr/Review/V74N4/0402_brainscience.html

what most people want. Augmented reality games don't seem like they're going to be enough of a killer app.

Then the answer might be work. Now, certainly, if you're designing 3D objects for a living, maybe you're going to wear this a lot because you're creating motorcycles or cartoon characters. That makes sense. But that's not what most of us are doing. Most of us spend a lot of time talking to other people as a part of our job, and AR can get in the way of that. And people who aren't talking to other people are often working with data. And data is two-dimensional. That is how the human mind interacts with data. Can you put data in three dimensions? People do it, but it rarely provides insight. Most of the time, data is better understood in two dimensions.

But maybe the pandemic is the key to the killer app for AR. If you imagine two people working on something together, and they're both working remotely. They want to work on this thing together. They like to be in the same space. We all know there's a real power to being in the same space with another person. But it's not always convenient to do that. And you could put on these headsets and use augmented reality to be in the same space potentially. Now, what is that like? Well, it's a little weird. Because it means you're going to have the other person be a cartoon in your world, and you're going to be a cartoon in their world. Do I want to be represented as some weird cartoon character in my professional doings? Maybe not. But look at this paper by Meta's Reality Labs:

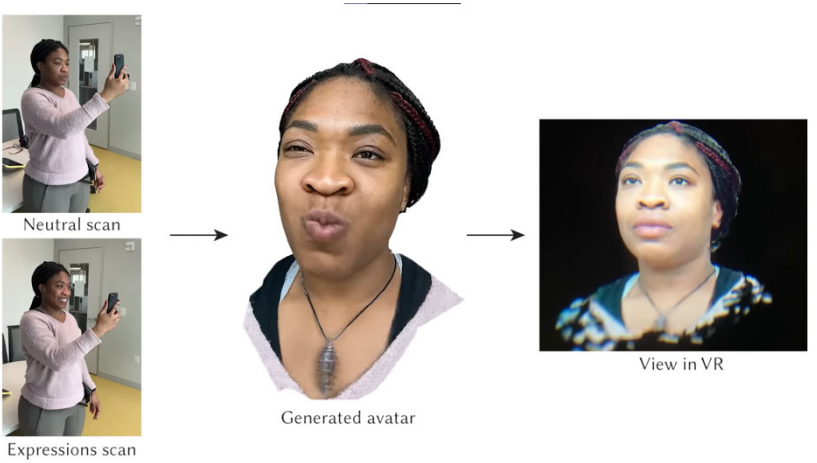
"We present authentic volumetric avatars from a phone scan. To create an avatar, a user can use an RGB camera, such as an iPhone 12, to capture a neutral expression from different viewpoints as well as a set of facial expressions. We use this data to generate the photorealistic avatar, which matches the user's face in terms of geometry and appearance and can produce high-fidelity renderings from novel viewpoints and expressions. Our volumetric avatar can be rendered in VR in real-time, which opens up the possibility for photorealistic telepresence applications."[28]

This is worth contemplating. By scanning yourself, you could create avatars that match your own physical self at another location. You've got a headset mounted on your face that can look at your eyes. It can look at what your face is doing and look at all your gestures and potentially make an avatar that moves and acts pretty much like you. This is interesting because the eyes are critical. They are a two-

28 Cao, Cen: "Authentic Volumetric Avatars from a Phone Scan (SIGGRAPH 2022)." *Cen Cao*, July 2, 2022. YouTube video, 7:17, https://www.youtube.com/watch?v=t7_TMD7v0Xs

way street. Information comes into the eyes, but lots of information goes out from the eyes. That's where our expressions happen, in the mask area of our face. And so, you have to create the illusion that two users are in the same room together, and both are making facial expressions and interacting naturally with each other, even though they are wearing masks.

Figure 5: Generated Volumetric Avatar Based on Phone Scans



Source: Screenshot from Cao, Cen: "Authentic Volumetric Avatars From a Phone Scan." https://www.youtube.com/watch?v=t7_TMD7v0Xs

The killer app for augmented reality could be the ability to create face-to-face communication, merging our spaces. And we're going to be able to do it very soon because mapping a space is hard, but mapping a space I'm in all the time, like my office, my living room, etc., is possible. You can map it and remember it. And out in the world, I don't want to wear a headset. That's weird. But in my office, in my house, I'm okay with that. We'll be able to connect and create these augmented reality pocket worlds with the people we want to communicate with using this technology very soon.

SO, WHAT IS THE METAVERSE?

The Metaverse isn't a place any more than the Internet is a place. The Metaverse is the blurring of real people, real places, and real things with virtual people, virtual places, and virtual things. You're blending the actual and the imaginary.

That's what the Metaverse is. And it's already happening without us even noticing it. When you go on Instagram, and you think*: Oh, I'm looking at my friend's life*—you're in the Metaverse. When you use a background in Zoom, you're in the Metaverse. When you send an invite to somebody in CLASH OF CLANS, you're in the Metaverse.[29] When you call somebody by their username, you blend reality and an artificial world, and you are in the Metaverse.

This is nothing new. Anytime somebody puts on makeup, or even when you put on clothing, you are blurred. You're covering up reality with something artificial and acting like it's normal. Even children playing with dolls, what are they doing? They are taking a physical object and turning it into a virtual person. This blurring of the actual and the imaginary is very human. Naturally, we want to use these technologies and are just starting. As these four technologies come together, this blurring between reality and imagination is what the Metaverse is. And I want to leave you with one last idea. These four technologies are important, but a fifth one is coming very soon. We will have AI characters that talk and listen, just like people do. Technologies like ChatGPT show that this is possible, and very soon, AI will be a critical part of the Metaverse.

Let's go twenty years in the future. Let's think about a child born into a world where this AI Metaverse is normal. How will they understand it? What will it be like for them? They will probably understand it as a set of magic glasses. These magic glasses are something they really are excited about because it lets them see and play with a virtual friend. And this virtual friend isn't just in one place. This virtual friend is there any time you put on the glasses. It's with you anytime, anywhere, spatially. This is important because children approach the world spatially. That's why they can't sit still: because they want to interact with everything spatially. Most adults will be kind of ashamed to run around outside, talking to an imaginary friend. But children are not ashamed. They will love it. This new friend will play any kind of game with them. This new friend is going to be up for any kind of adventure, and you can play with this new friend and your real friends simultaneously. You'll introduce your real friends to your imaginary friend, but more likely, your friends and their imaginary friends will all know each other already. The imaginary friends might be the ones who introduced the kids to each other.

You might say: *Oh man, parents will not be up for this.* But they will be because this imaginary friend is going to help children understand the world. It will be a very patient friend who's always ready to teach, who's always ready to blend

29 CLASH OF CLANS (Supercell, 2012, O: Supercell).

playing and learning seamlessly, who is going to have unlimited patience and unlimited understanding. It might seem weird at first to have children always accompanied by this super intelligent playmate they can only see with magic glasses. But what parent will be able to resist having this perfect guide and mentor that can help keep them safe and help them grow? This will be more than just a playmate. This is going to be someone who teaches children to see the world as it actually is.

The path to the Metaverse is going to be a long and difficult one. It's been long and difficult already, and we still have a long way to go. But as you think about it, you must remember why we are doing it. We are not just building another gadget for digital trendsetters. What we are doing is crafting the eyes of the next generation. There are dangers in that. If we do it wrong, it could be terrible. But if we do it, and it looks like we will do it, we should make these the best eyes the world has ever known.

LITERATURE

Baker, Joanne: "History: Beam Me Home," *Nature* 498 (June 27, 2013), pp. 430-431, https://doi.org/10.1038/498430a

Clark, Taylor: "How Palmer Luckey Created the Oculus Rift," *Smithsonian Magazine*, November 2014, https://www.smithsonianmag.com/innovation/how-palmer-luckey-created-oculus-rift-180953049/

Cline, Ernest: *Ready Player One*, New York, NY: Crown Publishers 2011.

Dunbar, Robin: "Neocortex Size as a Constraint on Group Size in Primates," *Journal of Human Evolution* 22, no. 6 (June 1992), pp. 469-493, https://doi.org/10.1016/0047-2484(92)90081-J

Eschner, Kat: "The Farmboy Who Invented Television," *Smithsonian Magazine*, August 28, 2017, https://www.smithsonianmag.com/smart-news/farmboy-who-invented-television-while-plowing-180964607/

Gabor, Dennis: "Holography 1948-1971: Abstract of Nobel Lecture, 11 December 1971," *Europhysics News* 3, no. 3 (1972), pp. 8-9, https://www.europhysicsnews.org/articles/epn/abs/1972/03/epn19720303p8/epn19720303p8.html

Gladwell, Malcolm: *The Tipping Point*: *How Little Things Can Make a Big Difference*, New York, NY: Little, Brown and Company 2000.

Hagen, Susan: "The Mind's Eye," *Rochester Review* 74, no. 4 (March-April 2012), pp. 32-37, https://www.rochester.edu/pr/Review/V74N4/0402_brainscience.html

Holt, Daphne J. et al.: "Neural Correlates of Personal Space Intrusion," *The Journal of Neuroscience* 34, no. 12 (March 19, 2014), pp. 4123-413434, https://www.jneurosci.org/content/34/12/4123

Khan, Sameen Ahmed: "Medieval Arab Contributions to Optics," *DOMES* 25, no. 1 (Spring 2016), pp. 19-35, https://doi.org/10.1111/dome.12065

Nipkow, Paul: "German Patent Specification No. 30105 Relating to the Invention of the Perforated Scanning Disc," *Science Museum Group*, no date [1884], https://collection.sciencemuseumgroup.org.uk/objects/co34827/copy-of-german-patent-perforated-scanning-disc-patent

N.N.: "AR/VR Headset Shipments Grew Dramatically in 2021," *International Data Corporation*, March 21, 2022, https://www.idc.com/getdoc.jsp?containerId=prUS48969722

N.N., "Volume of the VR Headsets Market Worldwide from 2018 to 2028," *Statista Market Insights*, August 8, 2023, https://www.statista.com/forecasts/1331896/vr-headset-sales-volume-worldwide

Slater, Mel: "Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments," *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, no. 1535 (December 12, 2009), pp. 3549-57, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781884/

Stephenson, Neal: *Snow Crash*, New York, NY: Bantam Books 1992.

Wheatstone, Charles: "Contributions to the Physiology of Vision. Part the First. On Some Remarkable and Hitherto Unobserved Phenomena of Binocular Vision," *Philosophical Transactions of the Royal Society of London* 128 (January 1838), pp. 371-394, https://doi.org/10.1098/rstl.1838.0019

VIDEO

Cao, Cen: "Authentic Volumetric Avatars from a Phone Scan (SIGGRAPH 2022)." *Cen Cao*. July 2, 2022. YouTube video, 7:17, https://www.youtube.com/watch?v=t7_TMD7v0Xs

GAMES

ALADDIN'S MAGIC CARPET EXPERIENCE (Disney Quest, 1998, O: Disney VR Studio)

APEX LEGENDS (Electronic Arts, 2019, O: Respawn Entertainment)

AMONG US (InnerSloth, 2018, O: InnerSloth)

CALL OF DUTY: WARZONE (Activision, 2020, O: Infinity Ward)

CLASH OF CLANS (Supercell, 2012, O: Supercell)

COUNTERSTRIKE:GO (Valve Corporation, 2012, O: Hidden Path Entertainment)

EVERQUEST (Sony Online Entertainment, 1999, O: Sony Online Entertainment)
FORTNITE (Epic Games, 2017, O: Epic Games)
LEAGUE OF LEGENDS (Riot Games, 2009, O: Riot Games)
PIRATES OF THE CARIBBEAN EXPERIENCE: BATTLE FOR BUCCANEER GOLD (Disney Quest, 2000, O: Disney Studios)
PIXIE HOLLOW (Disney Online Studios, 2008, O: Disney Online Studios)
PLAYERUNKNOWN'S BATTLEGROUNDS (Krafton, 2017, O: PUBG Studios)
ROBLOX (Roblox Corporation, 2006, O: Roblox Corporation)
SKYRIM (Bethesda Softworks, 2011, O: Bethesda Game Studios)
TOONTOWN ONLINE (Disney Interactive, 2003, O: Disney Interactive)
WORLD OF WARCRAFT (Blizzard Entertainment, 2004, O: Blizzard Entertainment)