ONE BONSAI

Learn Everything

YOU NEED TO KNOW ABOUT VR

In less than 30 Minutes

HOW

IT WORKS

ITS HISTORY

ITS BEST HEADSETS

ITS FUTURE

From Facebook to Google, the biggest tech companies in the world are investing heavily in VR software and hardware. From Walmart to the US Army, the biggest organizations in the world are integrating VR into their workflow. Millions of employees have been trained with VR and millions of gamers have played VR games.

The VR industry has come a long way since the Oculus Kickstarter in 2012, but it is still a burgeoning market growing at double-digits every year. As such, there's no central point of information you can visit to quickly gain a substantial understanding of the market and the technology.

That's what this guide intends to help you with. It will bring you up to speed with VR in less than thirty minutes. This ebook will explain how VR actually works, explain its history up until 2012, what some of the best devices on the market are today, and where the future of VR could lead us.

HOW? DOES VR WORK

Have you ever been so engrossed in a book or a movie that hours seem to fly by? You were so engaged with what you were reading or seeing that you forgot about yourself and the physical world you live in. You were fully immersed in a non-physical, imaginary world. Great works of creativity, whether books, movies, paintings, or other forms of art, are capable of moving people away from their own selves into the world that the artist has created.

VR relies on immersion too, but not quite the same type of immersion as you're used to. VR is at its best when it transports the user to a non-physical world. The difference with the immersion you feel when watching a movie is that VR has you believe it's really you who's in this new world. You don't forget about yourself. You're still in control, but you're somewhere else now. This feeling is called presence.

Here we will talk about the mix of technologies that help VR games and apps achieve that sense of presence. We explain stereoscopic displays, field of view, frame rate, refresh rate, and foveated rendering. These are all technologies that use your sense of sight to achieve presence. Of course, that's only part of the equation. Excellent audio and even haptics are incredibly important to increase your sense of presence in VR too. But sight is the most obvious one, and the one we'll focus on here.

You're somewhere else now

STEREOSCOPIC DISPLAYS

An ever so slightly different view is presented to each eye

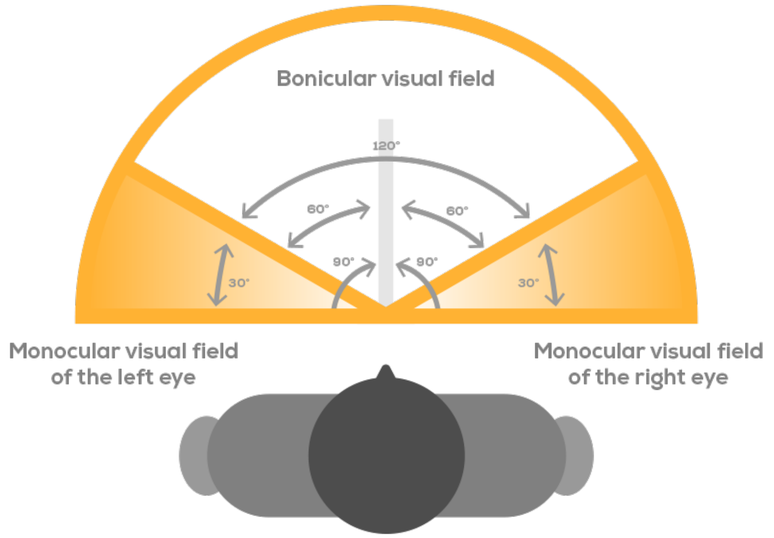
Let's first acknowledge that VR doesn't need photorealistic graphics to achieve a sense of presence. But it does need tailored content different from the content that we're usually served on our mobile and laptop devices. That's because a stereoscopic display emulates how human vision works. Our two eyes are a few inches apart from one another. This small separation means that each eye sees the world from a slightly different perspective. You can try this out right now: hold your thumb in front of you and look at it with one eye. Now switch to the other eye. It'll seem as if your thumb has jumped a bit from its previous position. The closer you move your thumb to your eyes, the more pronounced this jump will be.

This jump in perspective is how your brain determines how far an object is from you. It's one of the ways we perceive depth. As such, stereoscopic displays present a slightly different view of a virtual scene to each eye. It's what creates depth and how we feel as if we're really somewhere else. If it weren't for stereoscopic displays, there would be no VR.

FIELD OF VIEW

We see much more of the world than what our eyes are focusing on. The extent of our observable world is our field of view (FOV). Monocular FOV is the FOV for one of our eyes. Binocular FOV is where the FOV of both our eyes overlap. A human's total viewable area is anywhere from 200° to 220°. Our binocular FOV is between 100° to 120°.

The wider the FOV of a VR display, the more realistic it will seem and the more present you will feel. The closer the lens of a head-mounted display (HMD) is placed to your face, the wider your FOV will become. However, the image will become increasingly distorted too. While techniques such as barrel distortion can correct distorted images to a certain degree, HMD manufacturers still need to find the right balance between placing their lens close enough for a wide FOV, but far enough so the image doesn't look distorted.



The FOV of our eyes

FRAME RATE & REFRESH RATE

Anything that seems to move naturally on a screen is really just one still image after the other, but shown so rapidly that it seems continuous. Each still image is called a frame. Frame rate is how rapidly those images are presented to the viewer. This is generally the work of a computer's CPU and GPU. The more powerful those two, the more capable they'll be to generate more frames per second (FPS).

https://youtu.be/zquCIG3j9so

The general consensus is that VR should be presented to us at 90 FPS. So 90 images per second. This will provide the smoothest and most immersive experience. Anything below 90 FPS will come across as somewhat jarring, and it'll increase the chances of simulation sickness.

Refresh rate is sometimes confused with frame rate, but it's not the same. Refresh rate has more to do with the display than it does with the CPU and GPU of your device. It's measured in Hertz (Hz) and it explains how often your screen can redraw itself entirely. The Oculus Quest , for example, has a refresh rate of 72 Hz, which means its screen can refresh itself 72 times per second.

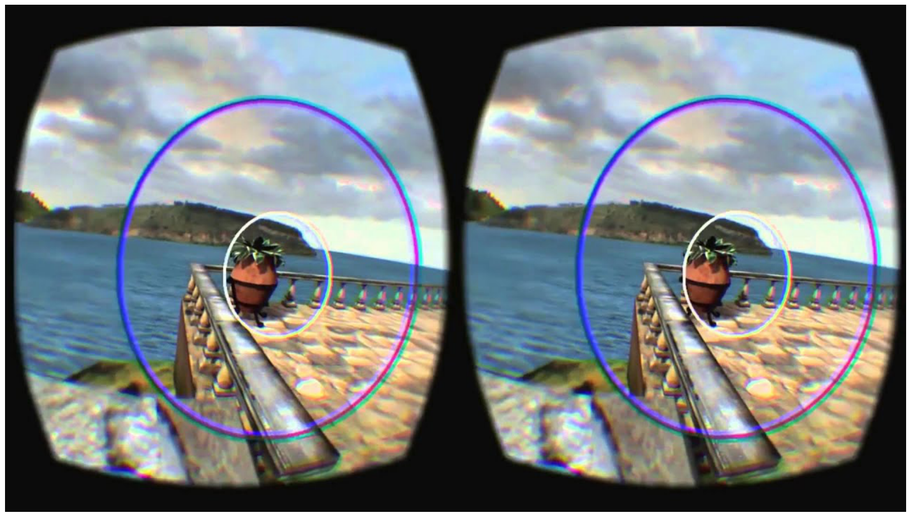
A display's refresh rate usually limits a device's frame rate. This is relevant for VR HMDs that are still hooked up to a PC. The display of the Oculus Rift, for example, has a refresh rate of 90 Hz. Even if your PC is powerful enough to produce 120 FPS, you'll be capped at 90 frames per second because of the display's refresh rate (if the two don't match, you'll experience something called *screen tearing*, where the images you see will seem torn apart).

FOVEATED RENDERING

Our eyes are very good at seeing the details of what we're focusing on. However, everything outsidethat narrow focus field, i.e. everything in our peripheral vision, will seem blurry. An upcoming graphics rendering technique that simulates this visual phenomenon is called foveated rendering.

Not only will foveated rendering make VR games and apps feel more realistic, but it will also drastically reduce the workload on standalone VR devices or on the devices that HMDs are hooked up to. After all, the image quality of everything in the peripheral vision can be drastically reduced, saving processing power and memory.

Foveated rendering requires eye-tracking technology to figure out what our eyes are focusing on. That technology is slowly being introduced to the market, but it's not quite ready to be introduced into consumer devices yet. The closest we have so far is the HTC Vive Pro Eye, an enterprise HMD priced at over $2,000.



Foveated rendering through eye-tracking

SUMMARY

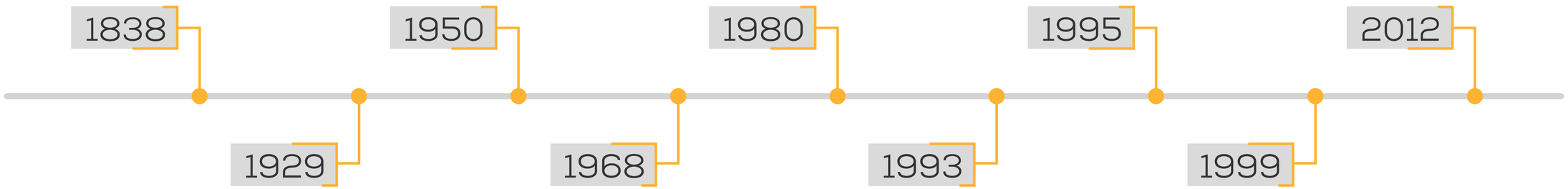
To sum it all up: stereoscopic displays present a different viewpoint to each of our eyes. Barrel distortion on curved lenses allows for a wider FOV. Frame and refresh rate make it seem as if we're in a world with continuous motion, and foveated rendering blurs what we're not looking at.

All these technologies have us believe that we're in a different world. It's what makes VR so effective and why it has applications in so many different industries. No other medium comes close to achieving this level of presence.

A BRIEF HISTORY OF VIRTUAL REALITY

Now that we know how VR works technically, let's explain how it came into being. This is a brief history of virtual reality, from its origin in the 19th century up until today. That's right, virtual reality isn't quite as new as you might think. In fact, VR has been a long time coming.

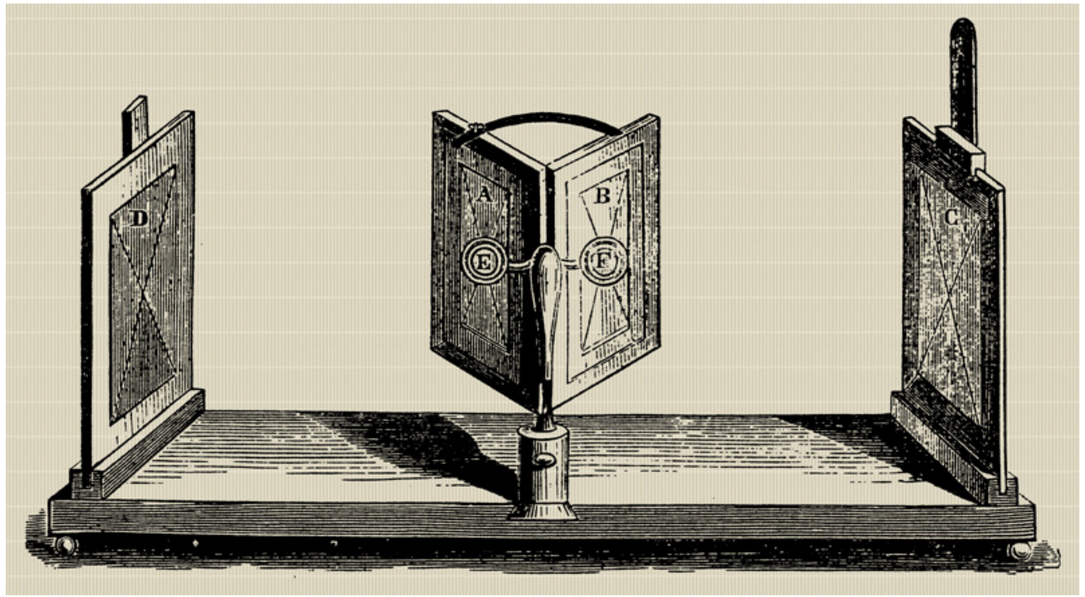
Think of it this way: as a species, we're naturally inclined to tell stories. The more immersive, the better. Throughout the history of time, we've used different mediums to tell those stories: murals in stone, parchment full of symbols, paintings of elaborate landscapes, books full of details. Virtual reality is just another medium to tell a story, except that it's the most immersive medium humanity has ever created.



1838

THE STEREOSCOPE

BY CHARLES WHEATSTONE



The stereoscope of Charles Wheatstone demonstrated that our brain processes a 2D image from each eye into a single 3D object with depth. This came to be known as stereopsis, and it's the basic premise that makes virtual reality... well... a reality. Interestingly, Wheatstone's stereoscope came into existence before photography The earliest-known photograph was taken in Paris in 1838, and the process of how it was taken was only unveiled in 1939. So the stereoscope was invented before it could be tested with actual pictures.

1929 LINK TRAINER

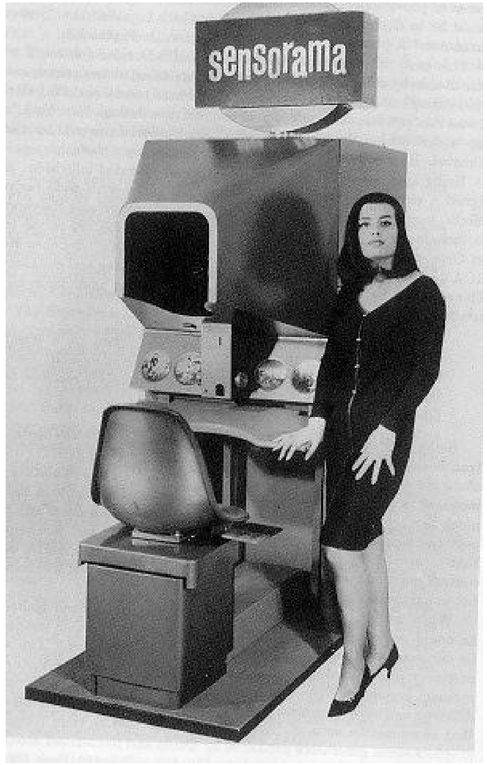
BY ED LINK

The Link Trainer, created by Edward Link in 1929, can be seen as the first commercial flight simulator. It was meant to safely and effectively train pilots, and it was used to train more than 500,000 US pilots during the Second World War, as well as the pilots from almost every other warring nation. The Link Trainer would pitch and roll as the pilot used the controls. Although there was no visual aspect, the Link Trainer still showed the power of an immersive environment to train people in a faster and more cost-effective way.

LATE
1950s

THE SENSORAMA

BY MORTON HEILIG



The Sensorama was well ahead of its time. Developed by Morton Heilig in 1958, this device stimulated all the senses. It had a stereoscopic color display, stereo sound, vibrations, and even atmospheric effects, such as a wind generator blowing wind through your hair. Unfortunately, the Sensorama remained a concept, because Heilig couldn't find investors to help him finance his project. Despite this, the device became an inspiration for computer scientists who wanted to create immersive environments.

1968 THE SWORD OF DAMOCLES

BY IVAN SUTHERLAND AND BOB SPROULL

Ivan Sutherland was already a well-respected computer scientist, because he had created the computer program Sketchpad, which helped pave the way for human-computer interaction. But he went a step further and designed what is now considered to be the first head-mounted display (HMD).

Along with his student, Bob Sproull, Ivan Sutherland created the Sword of Damocles, a piece of headgear connected to a computer that would let the user see grid-like surfaces superimposed on a real background. These grid-like surfaces changed in perspective as the user moved their head. But the device, apart from being awfully creepy, wasn't very practical. It was very heavy and required a mechanical arm to function, which is why it was never more than a lab project.

MID-
1980s

THE TERME “VIRTUAL REALITY”

COINED BY JARON LANIER

VIRTUAL
Reality

Jaron Lanier is an American computer scientist who’s widely considered to have coined the term “virtual reality.” In the mid-1980s, he founded VPL Research, through which he sold VR goggles and gloves. VPL stood for Virtual Programming Languages, and Lanier’s goal was to bring virtual reality into a mainstream audience. Unfortunately, the company filed for bankruptcy in 1990.

1993

SEGA VR

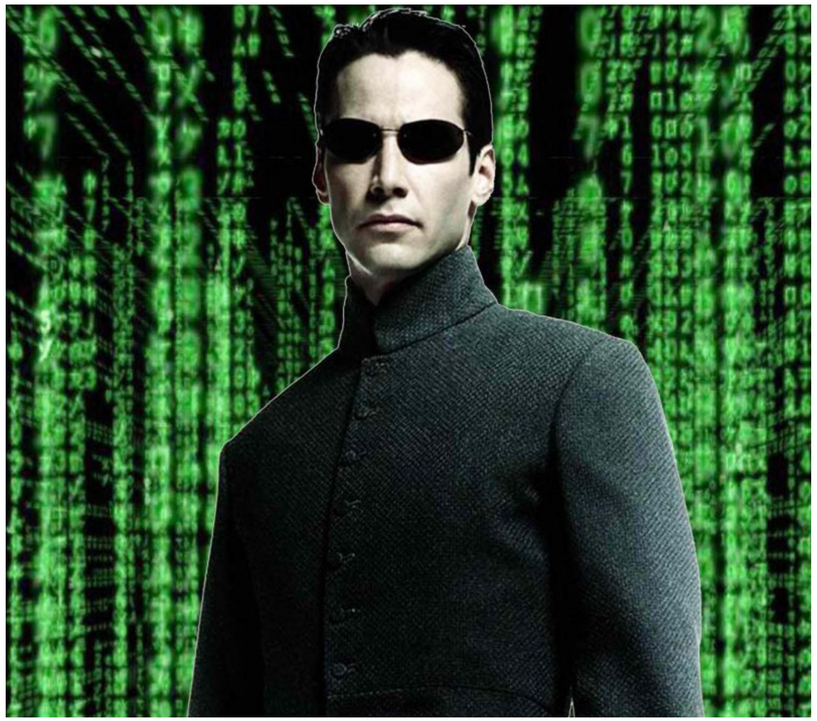
In 1993, Sega introduced the Sega VR, a virtual reality headset meant as an accessory for the Sega Genesis / Mega Drive console It was meant to be released with four launch games in 1994, but it remained a prototype and a flop for Sega. However, this was the first major example of a gaming company showing interest in VR.

1995

NINTENDO VIRTUAL BOY

Nintendo closely followed Sega's VR initiatives by introducing the Nintendo Virtual Boy, a gaming console that could display stereoscopic 3D graphics. Gamers would place their heads against the eyepiece to see a monochrome display. However, the Virtual Boy flopped as well, because of its lack of color in the graphics, and because the console wasn't comfortable to use.

1999 THE MATRIX



While the Matrix wasn't a technological innovation, it introduced millions of people to the idea of virtual reality, i.e. a different world that people could access by being "plugged in." Considered to be one of the best movies of the 90s, the Matrix helped move virtual reality from a hobby that only nerds should be concerned about into an extremely cool idea.

1968 OCULUS RIFT

THE KICKSTARTER CAMPAIGN

As you can see, the history of VR is riddled with flops and mistakes It took until 2012 before we arrive at the beginning of what could now be considered the "modern VR industry." It took so long for a variety of reasons, but mainly because hardware and lens technology had to become better and cheaper, and because 3D development tools had to be created for developers to work with.

The VR industry as we know it today started with the 2012 Kickstarter campaign of a new tech company: Oculus VR. They wanted to create the most immersive VR device for games, and had the backing from a big name: John Carmack, the creator of DOOM.

The Kickstarter campaign raised $2.5 million, far above its original goal of $250,000, and was marketed to bring 3D gaming to the next level. Only two years after the company's inception, Facebook bought Oculus VR for an enormous $2.3 billion. Since then, the company has gone on to release many different VR headsets, some of which are considered the best in the industry.

These were some of the most significant milestones in the history of VR. As you can see, even if a technology seems new, it likely has a very long history of technological advances to get to the point where it is now. Nothing comes out of nowhere. VR has been in the making for two hundred years, and it's finally stepping out of the shadows.

THE BEST VR HEADSETS OF 2019

Let's now address a few of the most prominent VR devices in today's market. What devices are considered to be the best VR headsets? Why? And how expensive are they? Read on to find out.

Three Different Categories

Before diving into the specific VR headsets, it's important to categorize them. There are three main categories for VR devices: smartphone VR, desktop/console VR, and standalone VR.

1

For the first category, your smartphone functions as the screen through which the virtual world is displayed, and the VR headset is the device that immerses you into that world. These headsets are generally much cheaper than other VR headsets, and they're a great way for most people to experience VR without spending a lot of money or time setting up a VR environment.

2

The second category requires a desktop or console to connect your VR headset to. It's a more complex and expensive setup, but it's generally a much more immersive experience too. Desktop/console VR is meant for people who want to understand the real capabilities of VR, for the aficionado gamers, or for those who use it professionally.

3

Standalone VR is an increasingly important category. With these types of headsets, you don't need an external device to connect to. The display and the processing unit are built into the actual headset. All you need to do is put on the headset and you're ready to go. This category is likely to soon become the future of VR.

SMARTPHONE VR DEVICES

GOOGLE CARDBOARD

BETWEEN $5-10 ON AMAZON

Google Cardboard is a brilliant move from Google. This device is the cheapest VR device on the market. Considering the near-zero cost, it still does a remarkable job of giving you an adequate VR experience. It's simple, affordable, and effective. All you need is a smartphone that runs at least Android 4.1 or iOS 8.0, which you shove into the cardboard headset, and you're ready to go.

It's great for companies who want to introduce VR to their customers or prospects, as the Google Cardboard is inexpensive and can be branded with your company logo and colors. Of course, there's only so much you can get for $15. The Google Cardboard gets uncomfortable after a while, and the only interactivity you have is the magnetic button on the side of the device.

DESKTOP/CONSOLE VR DEVICES

OCULUS RIFT S

AROUND $400 ON AMAZON

This is the device that started it all. The Oculus Rift started as a Kickstarter idea in 2012, before Facebook bought Oculus for a healthy $2.3 billion a few years later. The Oculus Rift has an OLED display, a resolution of 2160*1200, a 90 Hz refresh rate, and a field-of-view of 110 degrees.

For the full VR experience, you'll need to make sure you have the Oculus Rift accessories too: the Oculus Touch controllers, the Oculus Sensors (for room-scale tracking), and the detachable headphones that provide remarkably good quality of sound.

There's also the Oculus Rift S, which has a higher resolution (2560*1440) and better tracking, but a lower refresh rate and no adjustable lenses. Particularly considering the capabilities of the Oculus Quest (more on that below), Facebook seems to be slowly moving away from its Rift lineup.

DESKTOP/CONSOLE VR DEVICES

HTC VIVE PRO

> $1,000 ON AMAZON

The HTC Vive was the VR headset that blew the Oculus Rift out of the water when it was released in 2016. While the Oculus Rift has closed the gap quite considerably since, many still consider the HTC Vive to be the better headset, particularly when it comes to room-scale tracking. HTC has since come out with the HTC Vive Pro, a significant upgrade over the regular Vive.

The HTC Vive Pro has an OLED display, 2,880*1600 resolution, and a 90 Hz refresh rate. The device was built in collaboration with gaming company Valve, and so supports SteamVR out of the box. It's an expensive device, but it provides some of the most immersive VR experiences available on the market today.

DESKTOP/CONSOLE VR DEVICES

VALVE INDEX

FROM $800 TO > $1,000 ON AMAZON

The widely anticipated Valve Index is considered the best VR HMD on the market today, as it provides the best, most immersive VR experience. However, it's expensive and you need a very powerful PC to hook it up to: its minimum hardware requirements are Windows 10, 8 GB of RAM, an NVIDIA GTX 970+ or AMD RX480+, a Dual Core CPU, and a few USB 3.0 ports.

But the headset's specs are impressive. A display with a 1440*1600 resolution per eye, 120 or 144 Hz frame rate (depending on whether you participate in the Steam beta or not), adjustable interpupillary distance, and impressive off-ear speakers. The max FOV is 135 degrees, although that will depend on how close you position the screen to your eyes. If you have the computer hardware, money to spare, and you're looking for the best VR experience available right now, the Valve Index is the headset to buy.

STANDALONE VR DEVICES

OCULUS QUEST

AROUND $400 ON AMAZON

The Oculus Quest is widely considered as the first VR device capable of bringing VR to the masses. It's the best value-for-money VR headset on the market today, because it provides a good VR experience without requiring an expensive PC at a price point below $500.

The Quest has a display resolution of 1440*1600 per eye, a refresh rate of 70 Hz, the capable Snapdragon 835 as CPU, 4 GB of RAM, and excellent tracking. Facebook seems to consider the Oculus Quest as its most important VR device, as much of their research and new updates (such as hand tracking) are focused on the Quest only (and not the Rift)

If you want a good-enough VR experience that's untethered and that won't cost you over $500, the Oculus Quest is by far the easiest choice to recommend.

THE DISTANT FUTURE OF VIRTUAL REALITY

Now that we've talked about how VR works, explained the history of VR, and talked about some of the best VR devices are, let's talk about the future of VR. And for that, we need to take a small detour and talk about Artificial Intelligence.

AI keeps the techies awake at night. Bill Gates, Elon Musk, Sergey Brin, and even the late Stephen Hawking have all expressed their concern at the exponential growth of intelligence in AI. Broadly speaking, there are two types of AI – artificial general intelligence (AGI) and narrow AI – and both carry their own risks.

AGI means an AI that can learn and understand any intellectual task as a human can. We're still a long way from AGI, with many experts predicting it'll take decades, if not centuries. The existence of an AGI could be a sudden, existential threat to humanity regardless of our attempts to constrain it. In fact, those who have read Nick Bostrom's excellent book Superintelligence will know that there are very few scenarios where an AGI wouldn't lead to the extinction of humanity.

Narrow AI is what we currently have. It's an AI that vastly outperforms a human in a narrowly defined task. Examples are the Google Search algorithm, Alexa, or the algorithm that drives a Tesla. While we're quite familiar with this type of AI, it carries its own risks too. Already, narrow AI is being used to guide drones in autonomous warfare and to manipulate elections through fake news on social media. The pace of progress in this type of AI only exacerbates these dangers.

One of the ways to avoid the dangers of AI while also taking advantage of its increasing intelligence is to merge with it. This sounds more drastic than it actually is. After all, aren't we all cyborgs already? There's no denying that our smartphones and laptops have become extensions of ourselves. Society at large is already inextricably linked to technology.

What needs to change is the interface that we use to communicate with AI. Currently, we interact with our phones using two thumbs. We type on keyboards with ten fingers at a speed of forty words per minute. This severely limits the speed with which we can access and use technology. It's like trying to read a book with one eye closed and the other only half open. We need to increase our technology bandwidth to take full advantage of AI.

Drone warfare poses an ethical dilemma.
Should AI in a drone be able to pick its own target?

BMIs Increase Our Bandwidth

Brain-machine interfaces (BMIs) are the solution to this bandwidth problem. A BMI establishes a link between our brains and an external device. Eventually, a BMI will allow us to communicate directly with AI without limitations, while having direct access to its superior intelligence. The ultimate brain extension.

Of course, we're still a long way from such a device. Creating a BMI requires us to understand how we can get info out of the brain and into the brain. The former means that we should be able to accurately and instantly record the activity of billions of neurons, while the latter means we should be able to stimulate the right neurons in such a way that it produces the desired action.

As you can imagine, that's a hugely complex exercise. Establishing a colony on Mars seems peanuts in comparison. However, considering we're talking about negating an existential threat to humanity and creating a society that's exponentially more powerful than anything the world has ever seen, it's a challenge worth undertaking.

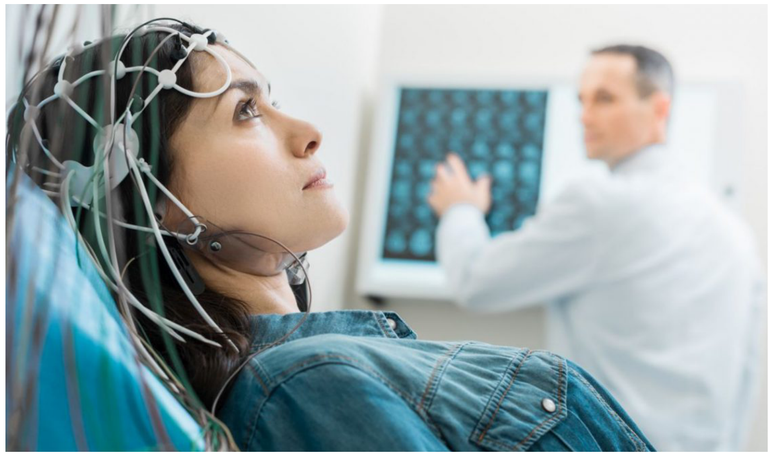
WaitButWhy has a fantastic primer on the brain that explains why creating a non-invasive, accurate BMI is so difficult. But don't be fooled into thinking BMIs don't exist yet. They do, and they're very useful. In fact, you might have come in touch with one already (no pun intended), as an EEG is an example of a BMI. It records the electrical activity as it happens in the different regions of the brain, and it's used to detect and monitor various medical conditions.

Control machines with your brain

The problem with an EEG is that it isn't spatially accurate. While it might tell you which specific regions of the brain are lighting up, there's no way an EEG can tell you which specific neurons are being triggered.

If we want a BMI that allows us to merge with AI, we'll need it to be at least two things. It'll need to be spatially accurate, in the sense that it should be able to record and stimulate very small regions of the brain, and it'll need to be temporally accurate, in the sense that it'll need to be able to record and stimulate regions of the brain instantly.

Additionally, in an ideal scenario, the BMI should be wireless, work across the whole brain, and should require surgery that isn't too invasive (i.e. that doesn't require drilling a huge hole in your skull). But, for the BMI prototype, spatial and temporal accuracy will go a long way already.



An EEG records electrical brain activity as it happens

Neuralink

It doesn't come as a surprise that Elon Musk is trying to solve this incredibly complex problem. In 2016, he founded Neuralink, a company that's dedicated to creating a functioning, wireless, high-bandwidth BMI which will eventually allow us to surf the waves of AI intelligence. Neuralink unveiled its plans on the 16th of July 2019.

Neuralink has created a device that's able to implant a thousand times more read-and-write electrodes into the brain than the next best device available. They've also created a robot that's able to quickly and precisely place those very small electrodes into the brain.

The applications of this device, and indeed how Neuralink will probably monetize the company, will be medical at first. Their BMI will help quadriplegic and paraplegic patients, giving back some of their functionality through prosthetic limbs connected to the Neuralink BMI. Imagine thinking and being able to move a robotic arm or leg. This is already possible, but Neuralink's device should be able to help patients do so faster and more accurately.

https://youtu.be/lA77zsJ31nA

Indistinguishable Worlds

Unsurprisingly, VR companies are interested in BMIs. After all, VR is all about immersion, and the higher the bandwidth with a virtual world (i.e. the more our real-world actions reflect our virtual actions), the more we'll feel immersed in it.

During the Game Developer Conference in San Francisco in March 2019, Mike Abinder, Valve's in-house psychologist, spoke about the possibility of using BMIs in VR headsets. More specifically, he spoke about using EEGs to better understand how a player is feeling during a game. This, in turn, will allow developers to create a game that'll respond to the gamer's bio-feedback.

For example, an EEG can tell you whether someone is scared, angry, or happy. When a VR-EEG horror game notices you're not all that scared, it could ramp up the intensity. Alternatively, if it notices you're scared to the point of quitting, it could introduce a gentler scene.

While this is all still highly speculative, it's not technically impossible. There's no reason to believe that we'll have progressed toward scenarios like this ten years from now. In fact, if we peer even further in the future, increasingly advanced BMIs paired with hyper-realistic VR could create worlds that are indistinguishable from real life.

Mike Abinder pretending to drill into Gabe Newell's brain

All the progress we're making in these areas make the simulation theory increasingly plausible. After all, if it's technically conceivable to create hyper-realistic other worlds, how do we know we're not living in a simulation right now? How do we know that everything around us is real and not created by an advanced race of aliens or humans?

There's no way of knowing the answer to this question, as the simulation won't have glaring errors that will uncover its true nature. Unless, that is, its creators have intentionally left such errors in the simulation, for us to discover when we're technically and psychologically ready to do so.

Well, I say "us" but that implies that everyone is sentient in the simulation. There's no reason to believe that either. The simulation's creators might well have created their simulation to occupy a single human being, for reasons we can't understand. Everything and everyone else could be programmed to create the semblance of a real world. The more the human interacts with someone it thinks is also a human being, the more realistic the simulation will make that person.

It doesn't really matter, though. Our definition of reality isn't attached to truth, but to experience. If what we experience feels real in every aspect, then that's our reality, whether the world we live in is simulated or not and whether we're all algorithms to serve one human being or not.

Westworld explored the topic of hyper-realistic, virtual worlds

CONCLUSION

This ebook has given you a comprehensive overview of how VR works, the history of VR, what some of the best VR devices are that money can be today, and where VR could lead us in the future Suffice to say that VR technology will be omnipresent in the future and has the potential to push our society into wonderful new avenues.

If you'd like to see how you can integrate VR into your company's workflow and how it can set you apart from your competitors, please don't hesitate to contact us . OneBonsai is a VR/AR provider that builds business solutions that improve health and safety, lower cost, and increase revenue for companies.

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