
What if I told you that this world around us, this richly textured world, were all just an illusion constructed in your head? What if I said that the real world has no smell or taste, no sound? What if I said there’s no colour? If you could perceive reality as it really is out there you wouldn’t recognise it at all (0:51-1:29).

I want to show you how the brain takes in information, sifts through it to find patterns and uses it to build the multi-sensory, technicolour show that is your reality (1:31-1:48).

When I’m in the world my senses are flooded with sights and sounds and smells and it seems obvious that reality is just out there, there’s a person, there’s a cab, all I have to do is show up and my senses let me experience it all. But there’s a twist to this story, let me show you something… (2:09-2:34).

*Story of the shaded square illusion…*

Your brain is trying to understand the colours of things irrespective of the lighting and the shadows, so somehow it’s not about what’s hitting your eyes, it’s about your brain’s interpretation (3:12-3:22).

Now this is about more than just a visual illusion, it’s about a fact that’s central to our lives: our perception of reality has less to do with what’s happening out there and more to do with what’s happening in here [i.e. in the brain] (3:28-3:43).

To understand what’s going on, we first need to understand how information from the world around us gets into the brain. It feels as if sights and sounds just stream in through our eyes and our ears, but imagine if you could climb inside a human skull. When you step into the skull you’ll find there’s no way for light or sound or smells to get directly in here (3:50-4:19).

This is a sealed chamber. So the brain sits in darkness and in silence. It’s in total isolation. Your brain’s never seen the outside world, but somehow you experience it. Now this might seem straightforward because we have portals to the outside world, like your eyes and ears, but these aren’t just piping in sights and sounds, instead photons of light or air compression waves, these are getting converted into the common currency of the brain: electro-chemical signals (4:25-5:04).

These signals travel through dense networks of brain cells called neurons. There are 100 billion neurons in the human brain, and in every second of your life each one of these is sending tens or hundreds of electrical pulses to thousands of other neurons, and somehow, all of this activity produces your sense of reality. So whether it’s the bark of a dog or the smell of a coffee or the view of a beautiful sunset, it’s all made of the same stuff in here. And this is the stuff of reality (5:08-5:54).

But how does the brain turn it into something meaningful? Well, it does it by sifting through the non-stop stream of incoming data to find patterns which it then assembles into a reality. It’s an operation which is the product of millions of years of evolution,
so efficient, so powerful, that its work seems effortless and instantaneous. Take as an example, sight (5:58-6:34).

*The story of the man who lost his sight and then got it back...*

What Mike’s story gives us is a glimpse of all the elements that have to be in place for the brain to construct a visual reality. Many regions of the brain are involved in vision, they specialise in different aspects, such as motion, edges, colours, face recognition. Somehow the brain weaves all of this together, unifies it, to form what we experience as an image. In Mike’s case, decades of blindness caused these regions of the brain to be taken over for other tasks, such as hearing and touch. They just weren’t available for him to use, even when he was given a pair of brand new eyes (10:38-11:23).

We often get our best view of how the brain operates when that operation is disrupted (11:33-11:40).

*The story of the experiment with left-right inverted vision goggles – prism world.*

What this exposes for me is, how much effort the brain goes through to construct our world, because, normally, you’re walking through the world, and it feels like, there’s reality out there, but, in fact, there’s so much work happening behind the scenes to allow reality to happen. Seeing requires an intensive training program, but new recruits come on board every day, we call them: babies (16:48-17:16).

When babies reach out to touch what’s in front of them, they’re not just learning what an object feels like, they’re learning how to see. They’re establishing pathways in the brain that will be used for the rest of their lives. Because vision is a whole body experience. The data coming in from our eyes only means something if we can cross-reference it (17:24-17:52).

If, from birth, you weren’t able to interact with the world, if you couldn’t work out through feedback what this sensory information meant, in theory, you’d never be able to see (17:54-18:06).

This cross-referencing doesn’t stop when we’re fully-grown. It continues throughout our lives. What we touch influences how we see. Taste is affected by our sense of smell. Our sight informs how we hear. Our senses depend on each other and our reality is built by comparing these streams of data. When they’re woven together, we get our perception of this moment. It’s an astonishing feat to pull off. But there’s one factor which really adds complication: timing (18:10-19:05).

All those streams of sensory data are processed by the brain at different speeds. For our reality to be constructed, they have to be synchronised (19:07-19:18).

*The story of the running track…*

When there’s a loud sound, it feels as though you react to it instantly, but you don’t. Watching sprinters in slow motion we can see that there’s a gap between the gun going off and their start. They may train to make this gap as small as possible, but their
biology imposes limits. Processing that sound and sending up signals to the muscles
to move will take around 2/10ths of a second. And that time really can’t be improved

*Test starting with a light rather than a sound. There is a slower start with the light
(4/100ths of a second) because visual signals are processed more slowly than auditory
signals in the brain.*

The astonishing thing is that our brains hide all this [the different time lags in the dif-
ferent sensory pathways]. When I clap my hands everything seems synchronised. Why?
Well your brain is pulling off fancy editing tricks. What it takes to be reality, is
actually a delayed version. It collects up all the information from the senses before it
decides on a story of what happened, and that means you live in the past. By the time
you think the moment now occurs, it’s already long gone. To conjure a reality from
all that sensory information, your brain needs about half a second. That’s the un-
bridgeable gap between an event occurring and your conscious experience of it. In
that half a second a lot of things need to happen (22:10-23:10).

Sometimes its easy to assume that there’s a single spot in the brain that takes care of
this or that function, like an area for memory or generosity or empathy. But in fact the
vast networks of the brain are so much more complex than that. Think of the brain
like a city. If you were to look out over a city and ask, ‘Where is the economy locat-
ed?’ you’d see that there was no single answer to that. Instead the economy emerges
as an interaction of all the elements. And so it is with reality. The raw materials of
perception are gathered by our sensory receptors, they’re turned into electrical sig-
als and transported around our brains along superhighways of neurons. Processed, they
become our reality. Some parts of brain city specialise in vision. Other districts care
about hearing, some about touch, and so on. And even within a sense, like vision, you
have streets that specialise in colours or edges or motion. But, just like in a city, no
neighbourhood operates in isolation. Instead the life of a city depends on the intera-
ctions between residents, at all different scales. And somehow, out of all of this inter-
action, emerges your personal reality (23:14-25:05).

Reality is the brain’s ultimate construction. It’s based on all the streams of data from
our senses, but it’s not dependent on them. How do we know? Because, when you
take it all away, reality doesn’t stop. It just gets stranger (25:11-25:33).

*The story of hallucination in solitary confinement (in the dark hole - no sound and no
light) at Alcatraz…*

This testimony goes to the heart of the relationship between the outside world, the
brain, and what we call reality. To understand it we need to look more deeply into the

This is the thalamus, one of the brain’s major junctions. Most sensory information
connects through here on its way to the outer surface of the brain, the cortex. So data
collected from the eyes stops here before going to the visual cortex. Now, you’d ex-
pect a heavy flow of information from the thalamus to the visual cortex, and there is.
But there’s six times as much traffic flowing in the opposite direction, and that dwarfs
the amount coming in from the eyes. And that suggests that in any one moment what
we experience as seeing relies less on the light streaming into our eyes and more on what’s already inside our heads (28:36-29:31).

**We all have this internally generated reality.** Incredible as it may sound, this world lives inside your brain. It’s constantly updated by information from our senses, but moment-to-moment, what we experience isn’t what’s really out there. Instead, it’s a beautifully rendered simulation. This is a surprising way to understand how you see the world. It’s called the *internal model*, and it’s vital to our ability to function (29:46-30:27).

My brain makes assumptions about what I am seeing based on my internal model and that’s been built up from years of experience of walking city streets just like this one. Instead of using my senses to rebuild my reality every moment, I’m comparing sensory information with a model that I’ve already constructed. Updating it. Refining it. Correcting it. Our brains are so good at doing this that we are normally unaware of it. But sometimes, under certain conditions, we can see the process at work (30:51-31:35).

*The story of the Einstein hollow mask…*

What you’re seeing is the internal model, not the raw information that’s coming in from your eyes. Your internal model is built on a lifetime of experience of faces that stick out. When you’re confronted with one that’s hollow, your model simply sees what it expects to see (31:56-32:20).

The visual cortex sends its internal expectations to the thalamus and the thalamus compares those to what’s coming in from the eyes. The difference between the two is what the thalamus sends back so the cortex can update its model (32:25-32:45).

Thanks to the internal model, the world out there remains stable, even when I’m moving. Let me show you what I mean (32:49-33:01).

*Story of using a video camera to simulate the movement of the eyes…*

So why does this video look so terrible, given that when I look at the buildings my eyes are making the same jerky movements. Although you’re not generally aware of it, your eyes move about four times a second, but your internal model operates under the assumption that the world outside is stable. So my eyes aren’t taking a video, they’re simply gathering bits of data, to update the city that’s already inside my head (33:25-33:56).

Having an internal model helps me make sense of my environment, and that’s its primary function – to navigate the world. The brain doesn’t bother picking up every detail, just enough to get us through, but it plays the trick of making us feel that we’ve seen it all (33:57-34:21).

*Story of the painting of the unexpected visitor and the eye-tracker…*

The internal model is a hastily drawn approximation, and more details are added on a need-to-know basis. When you look at the painting the first time you saw a sort of
rough draft of what was going on and when I asked you specific questions you had to go and answer those by looking, by turning your attention onto specific parts of the painting and only then did you actually see it. So placing your eyes on an object is no guarantee of seeing. But there’s something else we’re unaware of happening every time we look at any picture or person or thing. Any time we look at all (36:17-37:03).

We might think of colour as a fundamental defining quality of the world around us. After all it’s everywhere. But here’s the startling thing: in the outside world, colour doesn’t actually exist. When electro-magnetic radiation hits an object, some of it bounces off and is captured by our eyes. We can distinguish between millions of combinations of wavelengths, but it’s only inside our heads that any of this becomes colour. Add to that the fact that the wavelengths we can detect are only a small part of what’s out there. You experience reality as it’s presented by your senses and it doesn’t typically strike us that things could be very different. What we’ve been talking about so far is what we call the visible spectrum of light which is a spectrum of wavelengths that runs from what we call red to violet. But it turns out that this only constitutes a tiny fraction of the electro-magnetic spectrum - in fact, less that one trillionth of it. So all the rest of the spectrum, including radio waves and microwaves and x-rays and gamma rays, all of this stuff is flowing through our bodies right now and we’re completely unaware of it because we don’t have any specialised biological receptors to pick up on it. So what this means is that the part of reality that we can see is totally limited by our biology. And this isn’t just about sight. All our senses are only picking up a small part of the information that’s out there (37:05-39:06).

So for a dog, he’s tuned in to a whole world of scent molecules that I’m not. His experience of smell is as rich as my experience of vision. In the blind and deaf world of the tick the important signals are temperature and body odour. For cave dwelling bats it’s all about air compression waves that allow them to echolocate. But no one’s having an experience of objective reality, of the world that really truly exists. Instead, each creature perceives only what it has evolved to perceive. And this isn’t just about variation between species. If we’re each experiencing a personal reality, constructed inside our brains, how do I know that my reality is at all like yours? Most of the time it seems as if we operate along the same lines, as if you and I agree what a blue sky is, as if the sound of a dog bark provokes the same sort of response in both of us. But there’s a small group of people whose perception is measurably different from ours (39:12-40:41).

*Story about synaesthesia…*

These experiences come about because of the simple fact that inside the brain all sensory information is made from the same stuff – electro-chemical signals. Synaesthesia is the result of crosstalk between sensory areas of the brain. Think of the blurred borders between city districts. Synaesthesia shows us that even minute changes in brain wiring can lead to different realities.

There are different kinds of synaesthesia. Some people perceive weekdays to have locations in space. Some taste words, others see music, and every time I meet someone who has this kind of experience, it’s a reminder that from person to person, brain to brain, our experiences of reality can be quite different. For a small section of the population, that difference can be extreme and terrifying 42:05-43:20).
Reality differs from person to person and more than that, it changes from moment to moment. There are times in all our lives when it can seem enhanced, intensified. Even the one great constant which we all think we share, and which should never change, somehow becomes stretched and distorted. I’m talking about time. Time is something that we rarely stop to consider but our brain’s experience of time is often quite strange. It doesn’t always seem, in certain situations, that time is running at an even pace, sometimes it runs more slowly or more quickly.

The answer seems to lie with how our memories are made. In a critical situation, an area of the brain called the amygdala gets into high gear. It commandeers the resources of the rest of the brain, forcing everything to attend to the situation at hand. When the amygdala is in play memories are laid down with far more detail than in normal circumstances. These memories are richer and more vivid. If you’re ever in a similar situation you have more information at your disposal to work out how to stay alive. But as a fascinating consequence, as the events are replayed in your memory they appear to have taken a longer time. Jeb’s time distortion is something that happened in retrospect - a trick of the memory that wrote the story of his reality.

The brain is the universe’s ultimate storyteller. We believe whatever our brains serve up to us. The reality we take for granted requires intensive training to interpret the world. It takes time to process sensory information, so we live in the past. And because all that information is ultimately just electro-chemical signals to be sorted, matched, rendered and packaged, reality is something created inside our head. Our brain sculpts our reality using the narrow trickle of data that it can gather through the senses and from that trickle it tells a story about our world. It’s possible that every brain tells a different narrative. With seven billion human brains wandering the planet, trillions of animal brains, no one is tapped into the full picture. Each brain carries its own unique model of the world around us. That is what we experience. We have no choice. So what is reality? It’s whatever your brain tells you it is.