I know the feeling!

Look, hear, touch, tremble, get dizzy – and much more. Our senses are the only way we have of knowing that we and the world around us really exist. Yet everything we knew about our senses is changing.

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Picture caption:

Is it difficult to read the sentences on the following page? Don't worry. It's merely proof that a simple combination of colours is enough to puzzle our senses.

Feeling is not the same thing as perception. Your eyes feel the light almost always in the same way, but how you understand it can lead you to optical illusions or to connections with other senses, like pain.

Try to describe the fun of riding a roller-coaster using only your five senses. While you scratch your head trying to find out if the vertigo and the butterflies in your stomach fit into touch, vision, smell, hearing or taste, take the time to think about one more thing: how do you know your hand is really scratching your head, if you can't see it? If you want further challenges, look again at the previous page and answer: why does the image of a nail in the eye bring a painful feeling? Why does seeing a woman kissing a mouse churn your stomach? By the way, which one of the five senses told you that your stomach is sick?

Don't get dizzy with these questions (not least because dizziness is another case of a sensation that can't be explained just with hearing, vision, touch, smell and taste). As you probably suspect, based on the questions above, our senses are much more complex than we were always told. The idea that we have only five ways to perceive the world was sown by the Greek philosopher Aristotle, in the 4th century B.C. and, impressively, is still very popular. Science, nevertheless, has already noticed that we have over 20 senses which are highly malleable, complex and interesting. When scientists began studying the doors of perception, amazing things happened: people started to see with their tongues or ears, paint things that they had never seen, feel textures just by looking at something. This epitomizes the new science of the senses – and it can change everything that we know about the reality around us.

Is vision a single sense? Or are we talking of 4 senses, one for light and three others for each colour: red green and blue? Or even more? There is no consensus. The answer depends on the scientist to whom you ask the question.

Seeing All

How many ways are there to perceive the world? It's not an easy question, especially as, before we answer it, we need to know what world we are talking about. This is so because, in this case, there are two worlds: internal and external. The traditional 5 senses are specific to understanding what happens outside us. In addition thereto, we have senses that allow us to perceive ourselves and the relationship between our bodies and space. Even with your eyes closed, you know that you have feet, arms, head – an entire body, correct? The sense in charge of telling us what is part of our body is called proprioception. The British neurologist Oliver Sacks, in his book "The Man Who Mistook His Wife for a Hat", relates the true story of Christina who, at 27, lost her proprioception after taking antibiotics. From one moment to other, she was incapable of feeling her own body and had to learn to live using other senses, such as hearing and vision. She needed to see her own legs or hands in order to walk or grab an object. Speaking became very difficult – it is thanks to proprioception that we feel our mouth's movements.

Begin to travel through this internal world and new senses will pop up in front of you, telling you the status of your balance, blood pressure, thirst or hunger. One example of these senses is kinesthesia, which tells us when each part of our body moves. But some scientists believe that, even if we put all these senses together, we still don't have the whole picture. Who knows if each of these isn't just a simplistic grouping of many forms of perception? After all, feeling a cold touch is not the same as feeling a touch with pressure. And seeing shapes is different from seeing colours – which is proved by the fact that it is possible to be colour-blind. Would it be correct if we put together under the name "vision" the perception of shapes, reds, greens and blues? Or should we, rather than thinking in terms of vision, talk about at least four senses? Still, there is no consensus among scientists about what should be considered a single sense or otherwise. The different answers to these questions may cause our total number of senses vary between 10 and 33 (see table). Can you "see" the problem? So prepare yourself, because we are just getting started.

Exploring the relation between senses it is possible to enable people to see with their tongues or ears.

Making Sense

Our senses are like a gang: although they are large in number, they always act in groups. And activating one of them is enough to make all of them respond. Alvaro Pascual-Leone, a neurologist at Harvard University, in Massachusetts, USA, says that our brain is always using all perceptions to create a mental picture. When you look at a pineapple, you can feel its spiny texture with your mind's hand, as well as mentally sensing its smell and bitter-sweet taste.

Why does this happen? Before we start, it is important to understand that sensation and perception are complementary, but different processes. Sensation is the passive part of everything, when we merely receive a stimulus. That's when the sound waves hit your hearing system, make the eardrum vibrate and, as electrical impulses, these waves are taken by the auditory nerve to the brain. At this point, perception takes place, assimilating, decoding and processing these data.

Our sensations are always working, but our perception varies a lot. It can be temporarily deactivated: as anyone who has had to attend a boring class can testify, it's possible to listen to words without really hearing anything. On the other hand, try to walk in a deserted, dark street and you will see how you can be much more sensitive to noises and shadows. This "turning off" is selective. When we want to hold a conversation in a noisy party, we need to ignore all parallel conversations, but if someone mentions our name we immediately change our attention focus. At Harvard University, the psychologists Daniel Simons and Christopher Chabris asked volunteers to count the passes made by one of the teams during a basketball match. While paying attention to the task, many of them failed to notice a person dressed as a gorilla, crossing the court. (Pay attention! Maybe there's someone calling your name while you read this article).

It is possible to have problems with perception – a neurological problem called agnosia, which prevents people from recognizing images, smells or sounds. There are cases of people that could not tell the difference between a circle and a square, even though they could see both forms perfectly. Oliver Sacks tells the story of a music professor with a degenerative problem in the visual areas of his brain which, little by little, lost its ability to see the whole of an image. He could just identify details or movements. The confusion was so great that at some point he could not understand a rose anymore, even though he could describe it with all the details. During a medical appointment, he mistook his foot for his shoe, and grabbed his wife's head to use on his own head, literally mistaking her for a hat.

MAKING SENSE OF THE SENSES The number of senses is different depending on the theory	Conservative	Accepted	Radical
SENSORY MODALITY			
Vision			
Light			
Colour			
Red			
Green			
Blue			
Hearing			
Smell			
2000 or more receptor types			
Taste			
Sweet			
Salt			
Sour			
Bitter			
Umami			
Touch			
Light touch			
Pressure			
Pain			
Cutaneous			
Somatic			
Visceral			
Mechanoreception			
Balance			
Rotational acceleration			
Linear acceleration			
Proprioception – joint position			
Kinaesthesis			
Muscle stretch – golgi tendon organs			
Mulcle stretch – muscle spindles			
Temperature			
Heat			
Cold			
Interoceptors			
Blood pressure			
Arterial blood pressure			
Central venous blood pressure			
Head blood temperature			
Blood oxygen content			
Cerebrospinal fluid pH			
Plasma osmotic pressure (thirst?)			
Artery-vein blood glucose difference (hunger?)			
Lung inflation			
Bladder stretch			
Full stomach			
TOTAL	10	21	33

Even more striking are the cases in which sensation doesn't happen, but perception does. Our brain is able to feel textures through vision (look at a furry puppy, for example), or create images using the touch. The Turkish painter Esref Armagan was born blind and his eyes can't detect any kind of light. Nevertheless, he is able to paint complex images, like landscapes or fish, respecting perspective. He can even picture distant objects, like mountains and clouds. How is this possible?

First of all, he knows the objects by touch and also by the explanations of people with sight. In order to know what he is painting, he uses a special paint, the texture of which allows him to feel his own brushstrokes on canvas. But apart from this, the real secret is in Armagan's head. The visual cortex (area of the brain responsible for processing images) can work even without direct stimulus. For example, if you close your eyes and imagine a scene, your brain will activate the area responsible for the images, although with a lower intensity. The same happens with Armagan's brain: low activity in the visual cortex when he imagines an image, becomes much higher when he is painting. At these moments, his visual cortex activity is practically the same as that of a sighted person. Using memories, touch, descriptions, spatial locations and other senses, he can make an image that is very close to the one we have when we see something.

Defining vision seemed an easy task, but now it becomes more complicated: a person with agnosia reacts to light, but cannot identify objects. Armagan doesn't detect light, but uses the information he has in order to "see". His sight is good enough to allow him to paint better than many perfectly sighted people. Cases such as his reinforce the theory that perception doesn't exactly depend on the way the brain gathers information. In other words, the brain can use many different means to "see" – and the eyes happen to be only the most traditional.

There are many substitutes for a sense. If eyes fail, the brain has to "see" with sounds, descriptions, memories or any information available.

Seeing with the tongue

Some volunteers for research in England had to do nothing but put their arm under a table. On the table there was a rubber arm, like those used in magic shows. Both the real and the fake arms where touched at the same time by the same objects. The mapping of brain activity proved that only 11 seconds were needed for the volunteers to feel that the fake arm was the real one. At the end of the experience, many volunteers pointed to the rubber arm as being their real arm. Alvaro Pascual-Leone, a Harvard neurologist went further: he made sighted-people spend 5 days wearing special glasses that prevented them from seeing any light. During this period, they related an increase in their other senses, as well as some visual hallucinations. Furthermore, tactile or audible stimuli were capable of activating their visual cortex. All these alterations were gone 24 hour after the volunteers took off the glasses.

Both experiments show that our senses are much more flexible than we used to believe. As they are all connected, if you limit one of them somewhat, the others will try to compensate for the deficiency. In the first experiment, vision interacted with – and in the end, substituted – proprioception. In the second one, Pascual-Leone believes that the visual cortex of the volunteers started to adapt to working with non-visual stimuli. In both cases, what was really important to the brain was the information available. With the data gathered, the brain tried to construct a mental image.

Findings like these opened a path to finding ways to compensate for the lack of a specific sense, as in cases of blindness or deafness. One of the most promising

results is the vOICe, a device created by Dutch inventor Peter Meijer to make people see with their ears. A sound pattern is used to describe images recorded by a camera, which can be embedded in the glasses of the visually impaired. High sounds indicate an object in a high position, such as a shelf, while low sounds indicate things near the floor. Volume is related to the intensity of light: the brighter the object, the louder it sounds. No light (or the colour black) is represented by silence. It may sound weird, but after a little training the system can guide a person through a room.

Something similar can be done with taste. From the University of Wisconsin, USA, comes the BrainPort, which comprises 144 electrodes laid-out in a stamp-sized square, in contact with the tongue. The mountaineer Erik Weihenmayer, who has been blind for more than 20 years, used the device to project onto his tongue the images registered by a camera attached to his head. With a little training, he was able to identify objects and grab a moving ball. Cheryl Schilts, in the USA, used the BrainPort to regain her sense of balance. In her case, a device placed on the top of her head registered every tilt and the electrodes told her she was off balance – leaving the head upright would generate a stronger sensation in the centre of the tongue. It was enough for Cheryl to walk down the street, climb and descend stairs, and even carry a tray.

This voyage through the senses is just beginning. Each one of these new devices leads to further discoveries of how we perceive the world, which lead to more advanced technologies. Maybe someday scientists shall conclude that we have more than 35 senses or, who knows, there is an even more radical answer: just one. Since what is in question is nothing short of the way we see the world and how we know everything exists, maybe such research will change our entire relationship with reality. What will we be seeing and hearing some decades from now? No one knows.