Neural networks shed light on how we see gloss

We like glossy things—the gleaming paint of a new car, a slick of fresh nail polish, the skin of a succulent cherry. Scientists have now shed light on how our brains learn to see glossy materials— and perhaps many other properties of the world around us. In an article published in Nature Human Behaviour, the researchers demonstrate an artificial visual system that spontaneously learns to differentiate glossy and matte materials, and can even predict human visual illusions involving glossiness.

It might seem odd to ask how the brain tells glossy from matte things, given how obvious the difference normally appears to us. "But this question actually opens a door to a deep puzzle," says Dr Katherine Storrs of Justus Liebig University Giessen, who led the research. "Objects can create an infinite variety of images depending on the viewing conditions. Somehow our brain has to be able to interpret images it has never seen before."

The brain is remarkably good at solving these challenges in order to figure out what objects are made of, such as whether the material is glossy or matte. But we also sometimes make mistakes, and studying those errors can give us insights into the brain's inner workings. Professor Bart Anderson, of the University of Sydney, another author of the study, had previously investigated many striking illusions of gloss perception. For example, bumpier surfaces tend to look glossier. But why does the brain confuse bumpiness and gloss? The researchers hypothesised that the process of learning to see determines which visual cues our brains rely on, and therefore why we sometimes make mistakes.

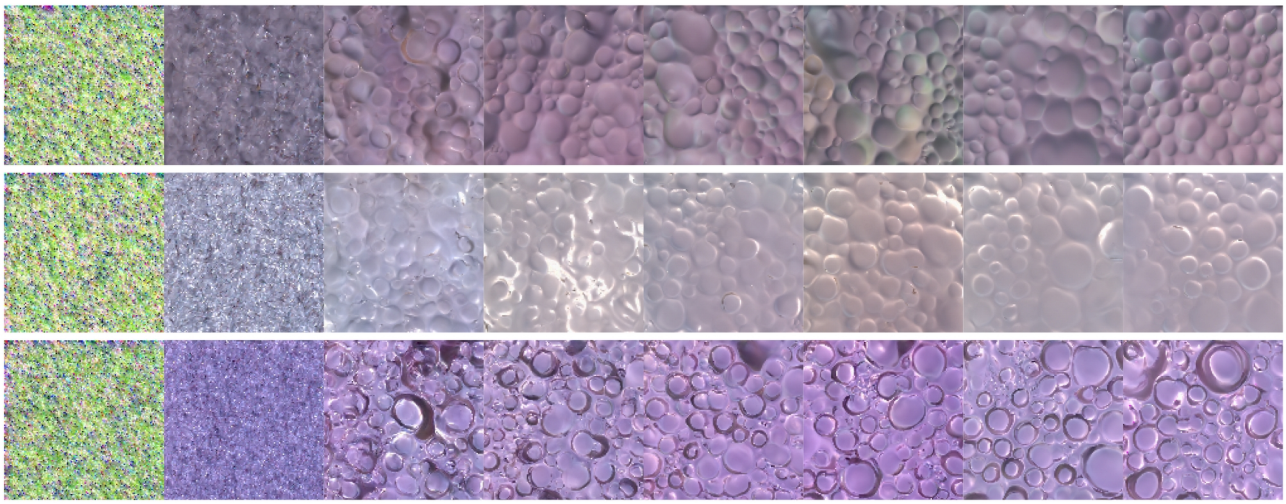
A glossiness illusion: all three surfaces are made of identical materials. Yet people tend to see the more bumpy surfaces, towards the right, as being more glossy or shiny.

"Since we don't get extensive training in how to tell different materials apart, we reasoned it must be something we're able to learn from visual experience alone," says Professor Roland Fleming of Justus Liebig University Giessen, who heads the research group where the work was conducted. To test this hypothesis, the researchers took advantage of recent advances in computer vision systems called "unsupervised" deep neural networks.

"When you train most neural networks, you start by telling them what they're looking at," explains Dr Storrs. "If you want the network to recognise objects, like a cat or a table, you show it millions of correctly-

labelled examples during training." The intriguing thing about *unsupervised* networks is that they learn how images are structured without being told what is in the images. This makes them very appealing as models of how humans and other animals might learn to see.

After seeing thousands of examples of surfaces with different materials, lighting, and shapes, the unsupervised neural networks learned enough about the 'look' of such images to generate brand new examples. By inspecting how artificial 'neurons' in the network responded to new images, the team could see that the networks had learned to tease glossy and matte surfaces apart.



Neural networks learning to generate images: At first the networks generated random noise images (left). But after seeing thousands of examples, they gradually learned to create realistic glossy and matte surfaces (right).

"We showed human volunteers the same images as we showed to the networks, and compared their perception of gloss," says Prof Fleming. "Remarkably, the unsupervised networks not only predicted the broad successes of human material perception. They also reproduced the distinctive illusions"

"Glossiness is just a starting point," says Dr Storrs. "The really exciting idea is that if the brain learns about different materials by experience, maybe it can also learn about all sorts of other important visual properties this way—shape, distance, size, or even properties that we perceive through other senses like hearing and touch."

Reference: Storrs, K.R., Anderson, B.L., & Fleming, R.W. (2021) Unsupervised learning predicts human perception and misperception of gloss. *Nature Human Behaviour.* https://dx.doi.org/10.1038/s41562-021-01097-6

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