MIT Technology Review

Artificial intelligence / Machine learning

A radical new technique lets AI learn with practically no data

"Less than one"-shot learning can teach a model to identify more objects than the number of examples it is trained on.

by **Karen Hao** October 16, 2020

The mythical rhinocorn.

MS TECH / PIXABAY

MIT Technology Review

computationally expensive—and very different from human learning. A child often needs to see just a few examples of an object, or even only one, before being able to recognize it for life.

In fact, children sometimes don't need *any* examples to identify something. Shown photos of a horse and a rhino, and told a unicorn is something in between, they can recognize the mythical creature in a picture book the first time they see it.

Hmm...ok, not quite.

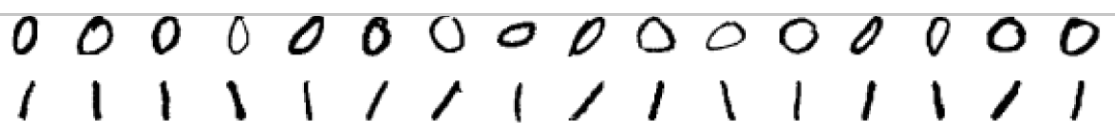
MS TECH / PIXABAY

Now a new paper from the University of Waterloo in Ontario suggests that AI models should also be able to do this—a process the researchers call "less than one"-shot, or LO-shot, learning. In other words, an AI model should be able to accurately recognize *more* objects than the number of examples it was trained on. That could be a big deal for a field that has grown increasingly expensive and inaccessible as the data sets used become ever larger.

How "less than one"-shot learning works

The researchers first demonstrated this idea while experimenting with the popular computer-vision data set known as MNIST. MNIST, which contains 60,000 training images of handwritten digits from 0 to 9, is often used to test out new ideas in the field.

In a previous paper, MIT researchers had introduced a technique to "distill" giant data sets into tiny ones, and as a proof of concept, they had compressed MNIST down to only 10 images. The images weren't selected from the original data set but carefully engineered and optimized to contain an equivalent amount of information to the full set. As a result, when trained exclusively on the 10 images, an AI model could achieve nearly the same accuracy as one trained on all



Sample images from the MNIST dataset.

WIKIMEDIA

The 10 images "distilled" from MNIST that can train an AI model to achieve 94% recognition accuracy on handwritten digits.

TONGZHOU WANG ET AL.

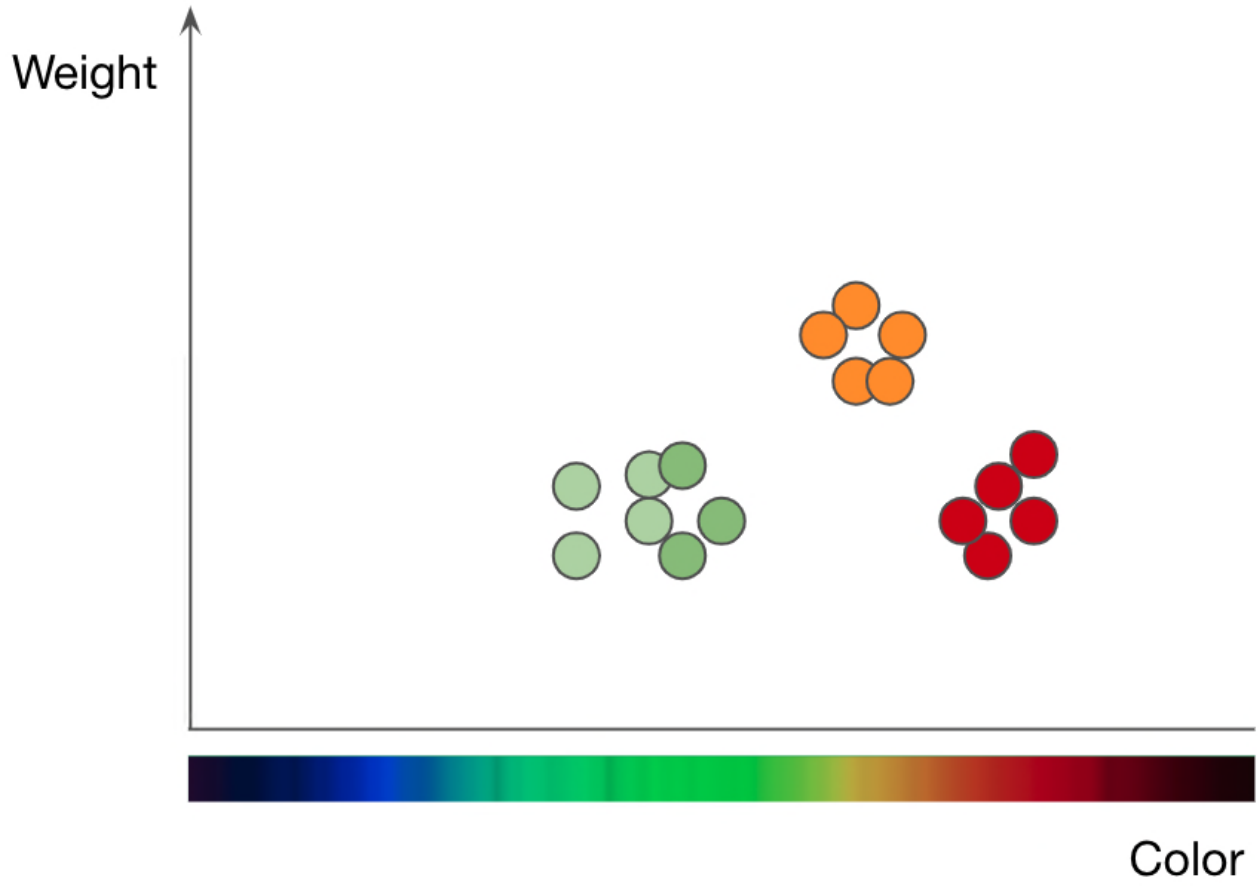
The Waterloo researchers wanted to take the distillation process further. If it's possible to shrink 60,000 images down to 10, why not squeeze them into five? The trick, they realized, was to create images that blend multiple digits together and then feed them into an AI model with hybrid, or "soft," labels. (Think back to a horse and rhino having partial features of a unicorn.)

"If you think about the digit 3, it kind of also looks like the digit 8 but nothing like the digit 7," says Ilia Sucholutsky, a PhD student at Waterloo and lead author of the paper. "Soft labels try to

The limits of LO-shot learning

Once the researchers successfully used soft labels to achieve LO-shot learning on MNIST, they began to wonder how far this idea could actually go. Is there a limit to the number of categories you can teach an AI model to identify from a tiny number of examples?

Surprisingly, the answer seems to be no. With carefully engineered soft labels, even two examples could theoretically encode any number of categories. “With two points, you can separate a thousand classes or 10,000 classes or a million classes,” Sucholutsky says.



Plotting apples (green and red dots) and oranges (orange dots) by weight and color.

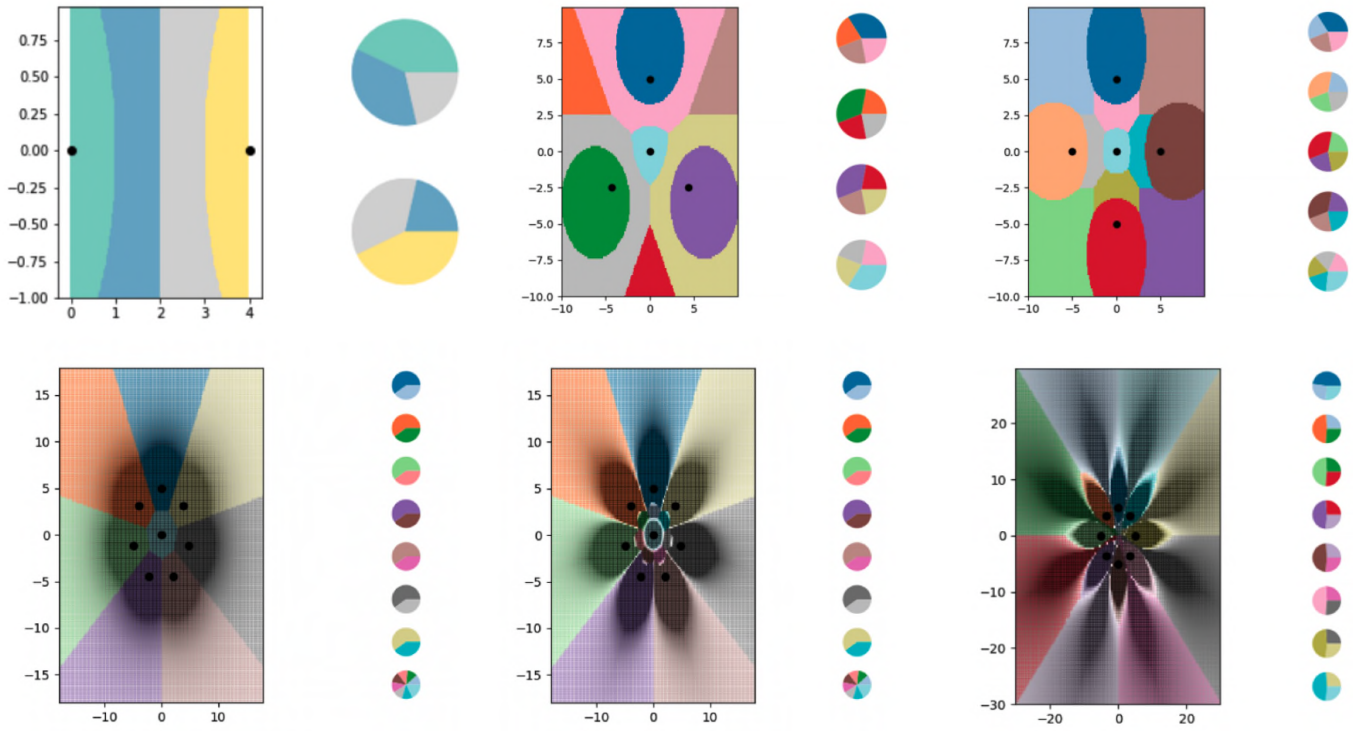
ADAPTED FROM JASON MAYES' "MACHINE LEARNING 101" SLIDE DECK

This is what the researchers demonstrate in their latest paper, through a purely mathematical exploration. They play out the concept with one of the simplest machine-learning algorithms known as k-nearest neighbors (kNN), which classifies objects using a graphical approach.

To understand how kNN works, take the task of classifying fruits as an example. If you want to train a kNN model to understand the difference between apples and oranges, you must first select the features you want to use to represent each fruit. Perhaps you choose color and weight, so for each apple and orange, you feed the kNN one data point with the fruit’s color as its x-

this point the plot is split neatly into two classes, and the algorithm can now decide whether new data points represent one or the other based on which side of the line they fall on.

To explore LO-shot learning with the kNN algorithm, the researchers created a series of tiny synthetic data sets and carefully engineered their soft labels. Then they let the kNN plot the boundary lines it was seeing and found it successfully split the plot up into more classes than data points. The researchers also had a high degree of control over where the boundary lines fell. Using various tweaks to the soft labels, they could get the kNN algorithm to draw precise patterns in the shape of flowers.



The researchers used soft-labelled examples to train a kNN algorithm to encode increasingly complex boundary lines, splitting the chart into far more classes than data points. Each of the colored areas on the plots represent a different class, while the pie charts to the side of each plot show the soft label distribution for every data point.

ILIA SUCHOLUTSKY ET AL.

Of course, these theoretical explorations have some limits. While the idea of LO-shot learning should transfer to more complex algorithms, the task of engineering the soft-labeled examples grows substantially harder. The kNN algorithm is interpretable and visual, making it possible for humans to design the labels; neural networks are complicated and impenetrable, meaning the same may not be true. Data distillation, which works for designing soft-labeled examples for neural networks, also has a major disadvantage: it requires you to start with a giant data set in order to shrink it down to something more efficient.

Sucholutsky says he's now working on figuring out other ways to engineer these tiny synthetic data sets—whether that means designing them by hand or with another algorithm. Despite these additional research challenges, however, the paper provides the theoretical foundations for LO-shot learning. "The conclusion is depending on what kind of data sets you have, you can

This is what most interests Tongzhou Wang, an MIT PhD student who led the earlier research on data distillation. "The paper builds upon a really novel and important goal: learning powerful models from small data sets," he says of Sucholutsky's contribution.

Ryan Khurana, a researcher at the Montreal AI Ethics Institute, echoes this sentiment: “Most significantly, ‘less than one’-shot learning would radically reduce data requirements for getting a functioning model built.” This could make AI more accessible to companies and industries that have thus far been hampered by the field’s data requirements. It could also improve data privacy, because less information would have to be extracted from individuals to train useful models.

Sucholutsky emphasizes that the research is still early, but he is excited. Every time he begins presenting his paper to fellow researchers, their initial reaction is to say that the idea is impossible, he says. When they suddenly realize it isn’t, it opens up a whole new world.

Pandemic Technology Project 7 hours

We investigated whether digital contact tracing actually worked in the US

A year ago, engineers built apps to track potential virus exposure. Our research shows the impact has been mixed—but there's still potential.

Biotechnology 1 day

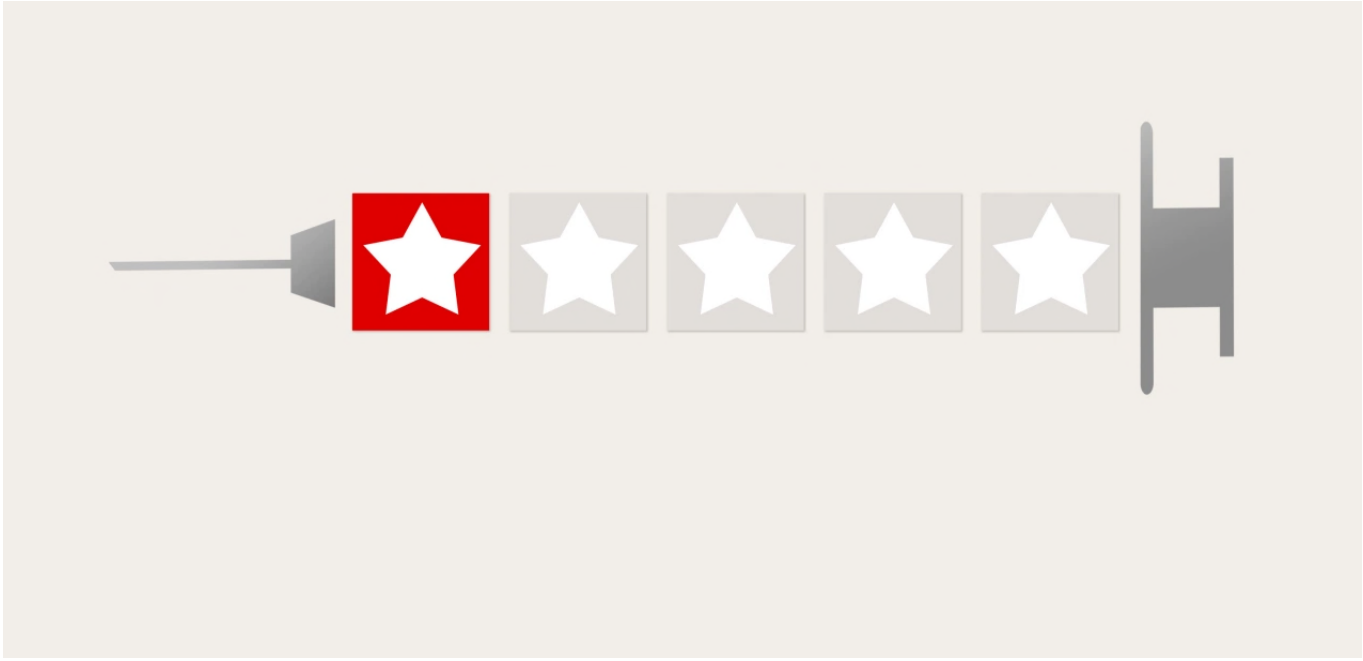
The Delta variant doubles the risk of hospitalization —but the vaccines still work

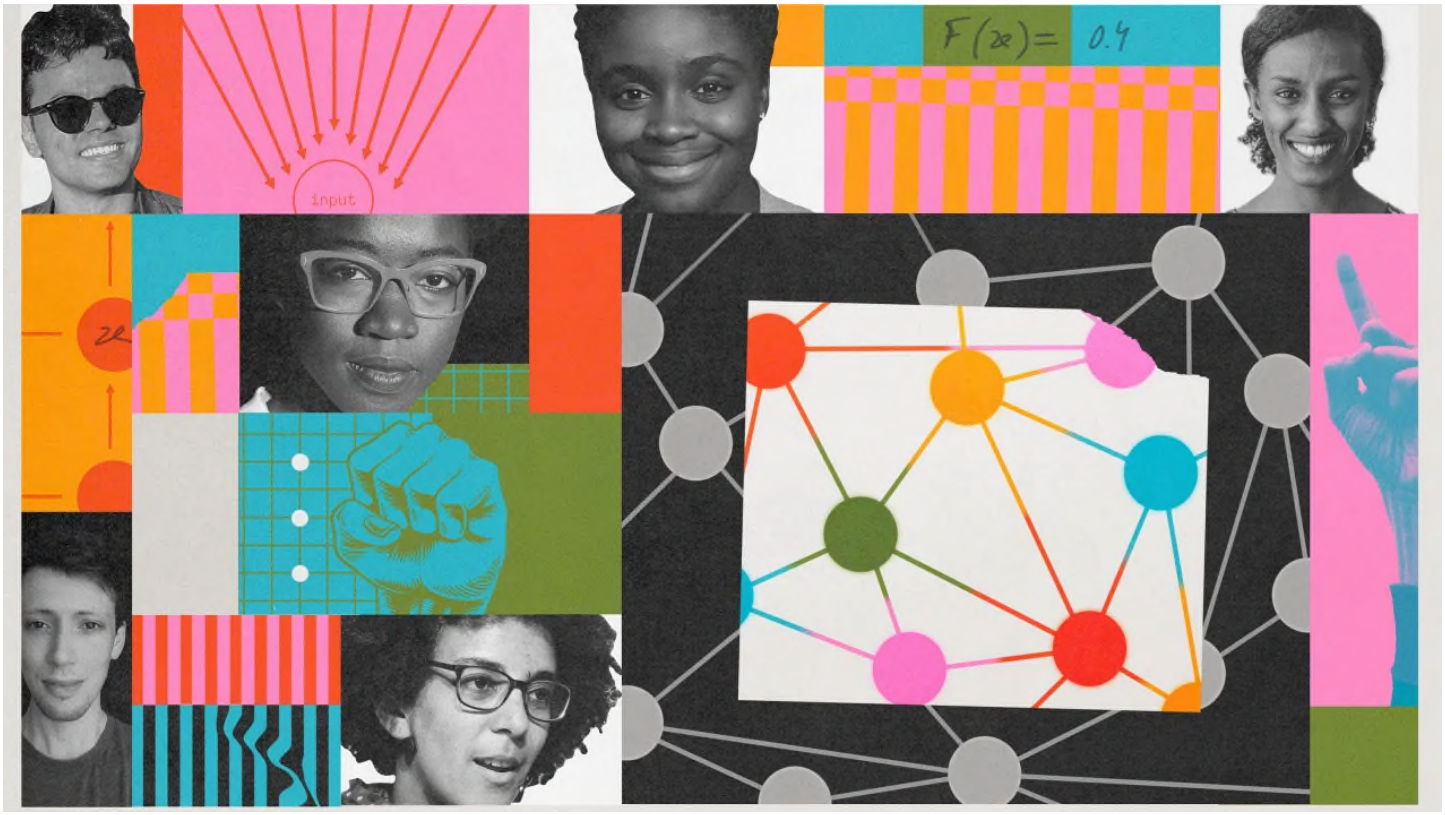
And being fully vaccinated provides significant protection.

Humans and technology 4 days

Anti-vaxxers are weaponizing Yelp to punish bars

MIT Technology Review



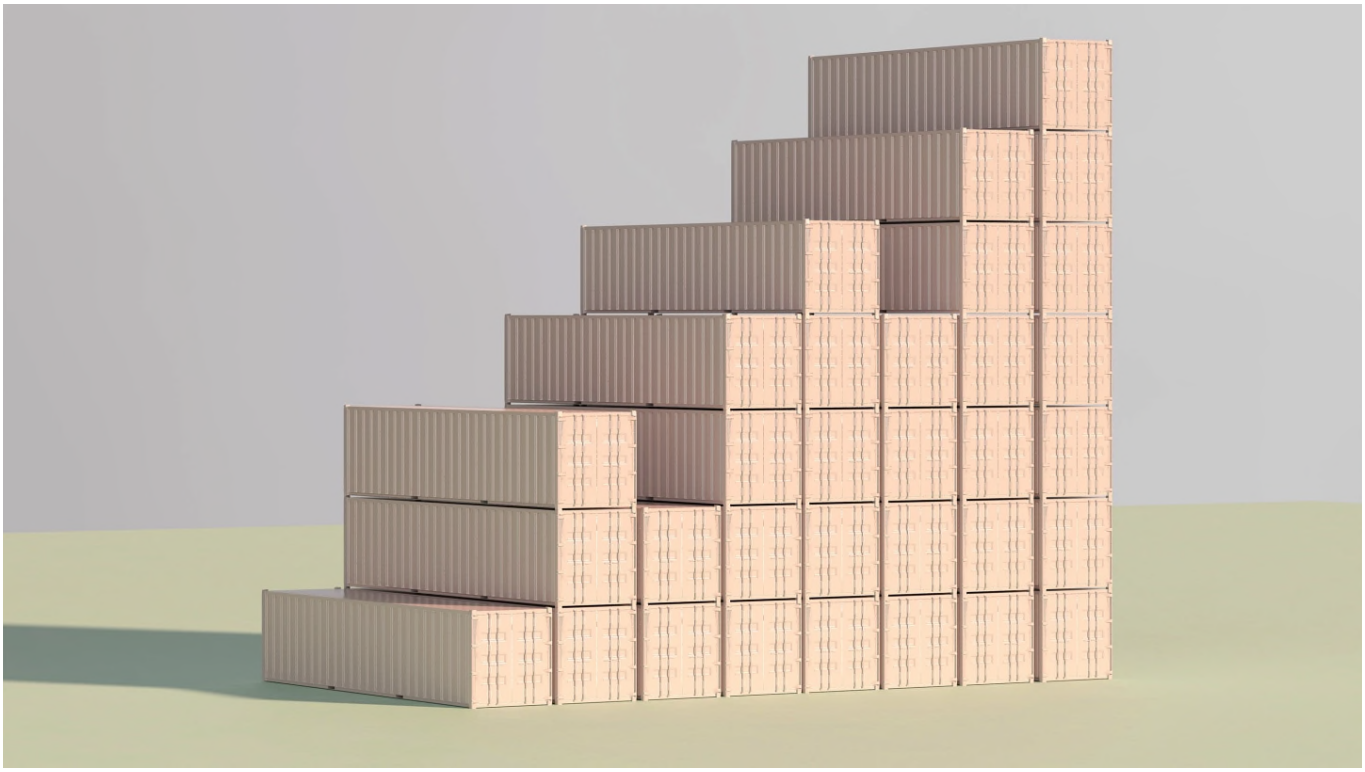


Biotechnology 6 days

What makes the Delta covid-19 variant more infectious?

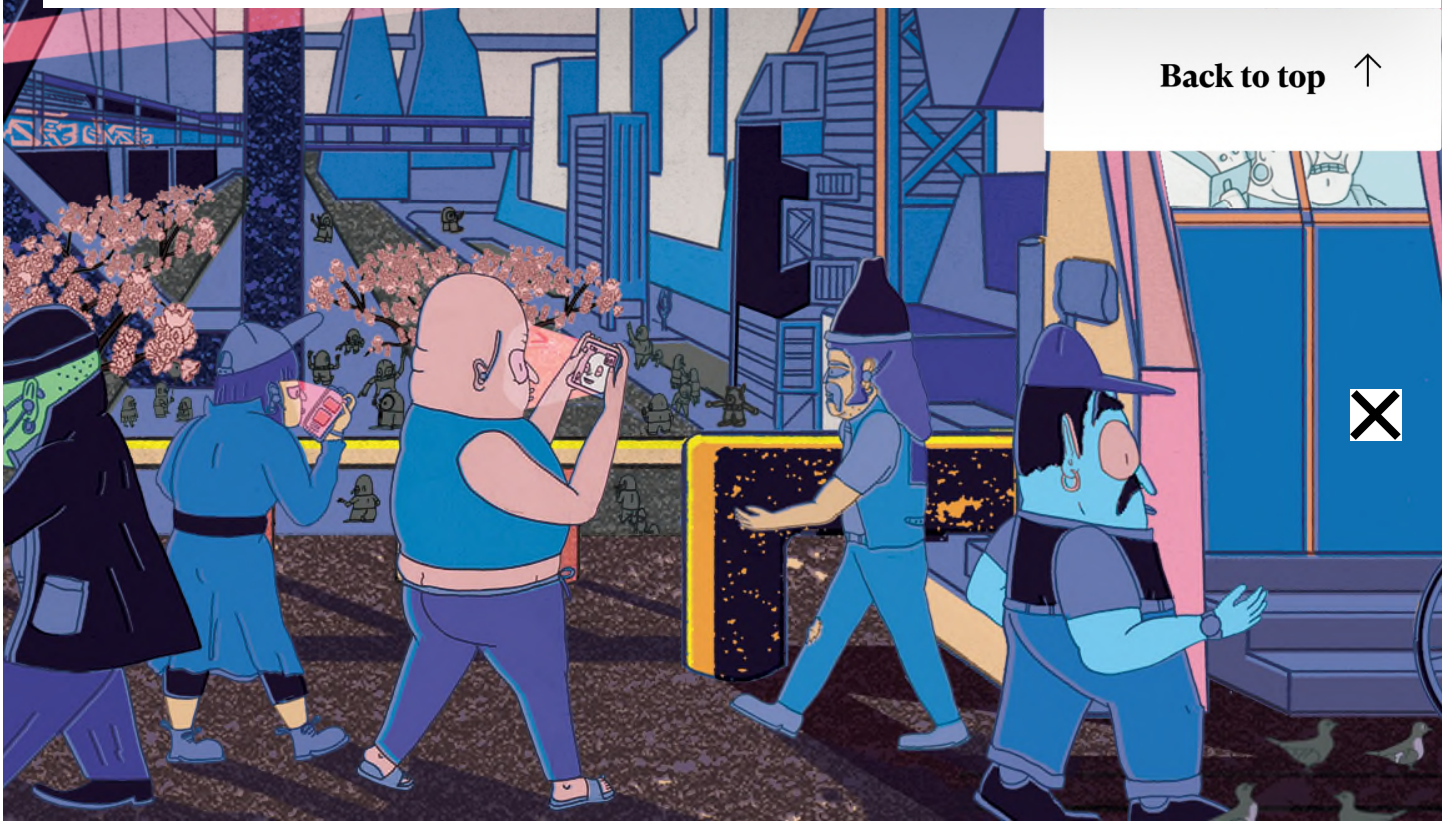
The variant, which first emerged in India, is already the dominant strain in the UK. Researchers are working to uncover the secrets of its success.

AI and other digital technologies have been surprisingly slow to improve economic growth. But that could be about to change.



Anti-vaxxers are weaponizing Yelp to punish bars that require vaccine proof

Cover Art by Dogboy



Back to top