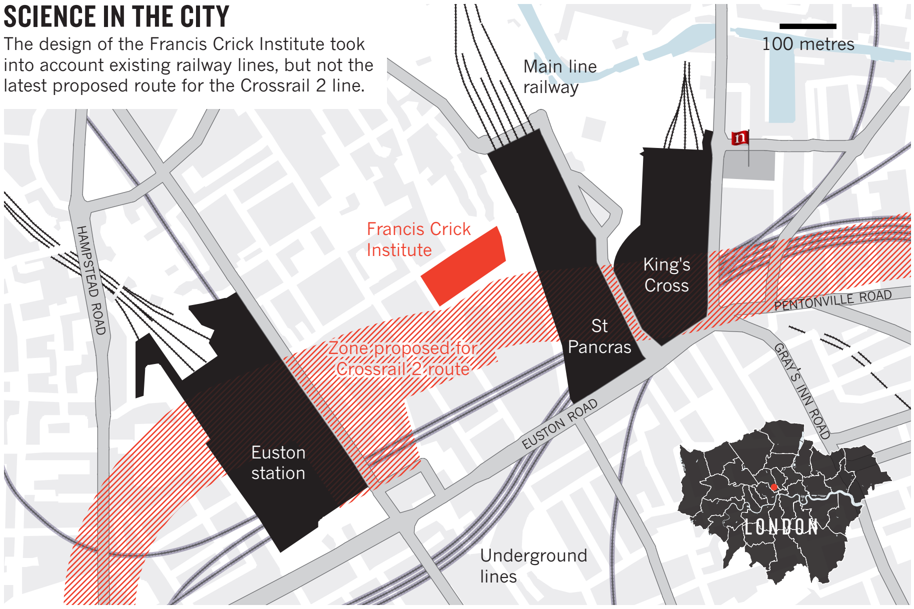
not impede any research activities due to interference from railway operations or construction works," says Savill. Transport for London (TfL), the local government organization that is driving the Crossrail 2 plans, says that it takes the concerns "very seriously". The MRC is now working with TfL to find a solution.

The Crick team would like Crossrail 2 to be diverted back to its former route, away from the institute. But Michèle Dix, managing director for Crossrail 2, says that plans have already changed because of concerns from the Crick. Among other things, the planned tunnel has been shifted farther underground. "You can't just keep on moving it deeper and deeper," she says, adding that further concerns should be addressed through engineering — for example by making the tunnel linings thicker.

Daniel Moylan, a TfL board member and a transport adviser to London mayor Boris Johnson, says that the mayor is a huge supporter of both Crossrail 2 and the Crick. The latter is a major element in Johnson's plans to promote the capital as 'MedCity' — a global hub for life-sciences research. Moylan is confident that the institute's "legitimate" concerns can be allayed by means of technical solutions.

Objections from Parisian academics in the first half of the twentieth century are said to have affected the route of the Métro, but there have also been more-modern conflicts between scientific equipment and transport infrastructure.



SCIENCE IN THE CITY

The design of the Francis Crick Institute took into account existing railway lines, but not the latest proposed route for the Crossrail 2 line.

In 2013, the proposed route of a US light-rail line was diverted after concerns from the University of Colorado Denver about the effects on spectroscopy and microscopes at its medical campus in Aurora. In 2011, the University of Maryland in College Park dropped its opposition to a new 'Purple Line' link to the Washington DC Metro once the local transportation agency agreed to bury and shield power lines.

Other labs have depended on engineering solutions. The New York Structural Biology Center, located near a number of subway lines, placed its most sensitive equipment on concrete slabs attached directly to Manhattan bedrock. It experiences no problems from vibration now, says executive director Willa Appel. If there is no solution in London for the Crick, Appel says, "tell them they're welcome to come here". ■

ARTIFICIAL INTELLIGENCE

DeepMind algorithm beats people at classic video games

Computer that learns from experience provides a way to investigate human intelligence.

BY ELIZABETH GIBNEY

DeepMind, the Google-owned artificial-intelligence company, has revealed how it created a single computer algorithm that can learn how to play 49 different arcade games, including the 1970s classics *Pong* and *Space Invaders*. In more than half of those games, the computer became skilled enough to beat a professional human player.

The algorithm — which has generated a buzz since publication of a preliminary version in 2013 (V. Mnih *et al.* Preprint at http://arxiv.org/abs/1312.5602; 2013) — is the first artificial-intelligence (AI) system that can learn a variety of tasks from scratch given only the same, minimal starting information. "The fact that you have one system that can learn several games, without any tweaking from game to game, is surprising and pretty impressive," says Nathan Sprague, a machine-learning scientist at James Madison University in Harrisonburg, Virginia.

DeepMind, which is based in London, says that the brain-inspired system could also provide insights into human intelligence. "Neuroscientists are studying intelligence and decision-making, and here's a very clean test bed for those ideas," says Demis Hassabis, co-founder of DeepMind. He and his colleagues describe the gaming algorithm in a paper published this week (V. Mnih *et al. Nature* **518**, 529–533 (2015); see also News & Views on page 486).

➲ **NATURE.COM**
For a video that peeks inside the offices of DeepMind:
go.nature.com/2kqata

Games are to AI researchers what fruit flies are to biology — a stripped-back system in which to test theories, says Richard Sutton, a computer scientist who studies reinforcement learning at the University of Alberta in Edmonton, Canada. "Understanding the mind is an incredibly difficult problem, but games allow you to break it down into parts that you can study," he says. But so far, most human-beating computers — such as IBM's Deep Blue, which beat chess world champion Garry Kasparov in 1997, and the recently unveiled algorithm that plays Texas Hold 'Em poker essentially perfectly (see *Nature* http://doi.org/2dw; 2015) — excel at only one game.

DeepMind's versatility comes from joining two types of machine learning — an achievement that Sutton calls "a big deal". The first, called deep learning, uses a brain-inspired architecture in which connections between layers of simulated neurons are strengthened on the basis of experience. Deep-learning systems can then draw complex information from reams of unstructured data (see *Nature* **505,** 146–148; 2014). Google, of Mountain View, California, uses such algorithms to automatically classify photographs and aims to use them for machine translation.

The second is reinforcement learning, a decision-making system inspired by the neurotransmitter dopamine reward system in the animal brain. Using only the screen's pixels and game score as input, the algorithm learned by trial and error which actions — such as go left, go right or fire — to take at any given time to bring the greatest rewards. After spending several hours on each game, it mastered a range of arcade classics, including car racing, boxing and *Space Invaders*.

Companies such as Google have an immediate business interest in improving AI, says Sutton. Applications could include how to best place advertisements online or how to prioritize stories in news aggregators, he says. Sprague, meanwhile, suggests that the technique could enable robots to solve problems by interacting with their environments.

But a major driver is science itself, says Hassabis, because building smarter systems means gaining a greater understanding of intelligence. Many in computational neuroscience agree. Sprague, who has created his own version of DeepMind's algorithm, explains that whereas AI is largely irrelevant to neuroscience at the level of anatomical connections among neurons, it can bring insight at the higher level of computational principles.

"The tricks we use for training a system might lead to new ideas about the brain."

Computer scientist Ilya Kuzovkin at the University of Tartu in Estonia, who is part of a team that has been reverse-engineering DeepMind's code since 2013, says: "The tricks we use for training a system are not biologically realistic. But comparing the two might lead to new ideas about the brain." A particular boost is likely to come from the DeepMind team's choice to publish its code alongside its research, Kuzovkin says, because his lab and others can now build on top of the result. "It also shows that industry-financed research goes the right way: they share with academia," he adds.

DeepMind was bought by Google in 2014 for a reported £400 million (US$617 million), and has been poaching leading computer scientists and neuroscientists from academia, growing from 80 to 140 researchers so far.

Its next steps are again likely to be influenced by neuroscience. One project could be building a memory into its algorithm, allowing the system to transfer its learning to new tasks. Unlike humans, when the current system masters one game, it is no better at tackling the next.

Another challenge is to mimic the brain's way of breaking problems down into smaller tasks. Currently, DeepMind's system struggles to link actions with distant consequences — a limitation that, for example, prevented it from mastering maze games such as *Ms. Pac-Man*. ■

NEUROSCIENCE

Researchers seek definition of head-trauma disorder

Guidelines should assist in diagnosis of brain disease seen in retired American footballers.

BY HELEN SHEN

Dave Duerson suspected that something was wrong with his brain. By 2011, 18 years after the former American football player had retired from the Phoenix Cardinals, he experienced frequent headaches, memory problems and an increasingly short temper. Before he killed himself, he asked that his brain be donated for study.

Researchers who examined it found signs of chronic traumatic encephalopathy (CTE), a degenerative condition linked to repeated head injuries. At least 69 cases have been reported in the literature since 2000, many in former boxers and American football players (P. H. Montenigro *et al. Alz. Res. Ther.* **6,** 68; 2014) — heightening public concern about concussions during contact sports. Yet much about CTE is unknown, from its frequency to its precise risk factors and even whether its pathology is unique.

Researchers now hope to take a major step towards answering those questions. At Boston University in Massachusetts on 25–27 February, neuroscientists will convene to examine the characteristics of CTE in brain tissue from post-mortem examinations. They hope to agree on a set of diagnostic criteria for the disease, and to assess whether it is distinct from other brain disorders, such as Alzheimer's disease.

The effort is sorely needed, says Walter Koroshetz, acting director of the US National Institute of Neurological Disorders and Stroke in Bethesda, Maryland, which is organizing the meeting. "The definition is the important piece that lets you do the rest of the research," he says. And the stakes are high. CTE is associated with memory loss, irritability, depression and explosive anger, which are thought to appear and worsen years after repeated head trauma. Research by Ann McKee, a neuropathologist