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Can a machine read your mind?

It sounds like science fiction, but politicians, lawyers and advertisers are falling over themselves to buy into the latest scientific discovery: brainjacking. Soon our secret desires and not so innocent thoughts could become public knowledge. John Naish investigates an uncomfortable trend

I'm sitting in a Sussex cottage, wearing a rubber swimming cap dotted with wires and electrodes. On a laptop in front of me, a constantly shifting wash of coloured graphics portrays the activity in my brain. It's a neat party trick, but it is also a Pandora's box: across the world, scientists are using this kind of technology to prise open our minds, to fathom our voting preferences, our guilty thoughts, our shopping desires, even the words we are thinking. Already their activities are stealthily changing our world.

I'm the guest of Dr David Lewis, a British neuropsychologist who uses electronic brain-scanning to help brands see which of their marketing strategies best snare our interest. His Sussex University-based company, the Mind Lab, uses equipment that monitors electrical activity in the brain, and is currently investigating how to refine people's enjoyment of video games. This is definitely the least contentious end of the market.

Amid all the scientific gadgetry and research, sceptics argue that brain-reading systems are not yet sufficiently developed to be of real use in any field. But in fact, that doesn't matter: the prospects are far too tantalising. Companies are already marketing the technology as a way to penetrate the last frontier of exploration – the space between our ears. Lawyers, military chiefs, advertisers and politicians are eagerly buying. Welcome to the world of brainjacking, where science fiction is happening now.

Last spring, for example, an Indian court found a young woman guilty of murder based, in part, on evidence of "guilty knowledge" revealed by her brain waves. Aditi Sharma, 24, a Pune-based MBA student, was interrogated while wearing an electroencephalogram (EEG) cap similar to the one I used. It monitored her brain activity while she heard statements that were either neutral or described the killing of her former lover. Prosecutors claimed that the "brain fingerprinting" test showed how memory areas of her brain activated when she heard incriminating details.

Although an Indian government panel of scientists says this technique, Brain Electrical Oscillation Signature profiling (BEOS), should be ignored, its use in India is spreading. In January, Ravindra Kantrole, a Mumbai petty criminal, was convicted of being "the Beer Man", a serial killer of seven victims, largely on brain-mapping evidence. Earlier this month, two priests and a nun were freed on bail in a murder case after BEOS tests showed "no memory of the killing".

Having your brain electronically scanned is not in itself the most encouraging experience. On Dr Lewis's screen, my inner world resembles nothing more intelligent than a duff television screen. But he says that he can use this squiggly data, along with measurements of heart rate, temperature and gaze, to gauge what is attracting my mind's attention. That's enough to win serious funds from media companies and car manufacturers.

Rapid developments in medical brain-imaging, most crucially in the use of functional magnetic resonance imaging (fMRI) scanners, mean that we are just starting to see much more of our mental workings. British neuroscientist John-Dylan Haynes, of the Max Planck Institute in Germany, has found how our intentions leave telltale traces in the brain. He is about to publish a study that shows how, by scanning the prefrontal cortex with an fMRI scanner, he can accurately predict in the lab what items we will want to buy.

Last year, researchers busted the brain's "content" barrier for the first time. Scientists at Carnegie Mellon University, Pittsburgh, showed people drawings of five tools (drill, hammer, etc) and five dwellings (igloo, castle) and asked them to consider each object. A report in the journal PLoS One says that the fMRI-scanned brain patterns associated with each object were so distinctive that the computer could tell with 78 per cent accuracy which one was on a volunteer's mind. The patterns were also remarkably similar from one person to another, so science may one day write a mind-reading dictionary that suits most people. The Pittsburgh team is now studying brain patterns that encode abstract ideas, to see if a dictionary can be written covering more complicated concepts.

Politicians are latching on to brain-scanning's potential for spotting which of their promises attract voters' approval. EmSense, a "neuromarketing" company founded in 2004 by seven Massachusetts Institute of Technology graduates, has developed a lightweight EEG headset resembling an Alice band that may show how wearers react to speeches and debates. The company claims it can "accurately and objectively evaluate how voters truly feel, what captures their attention and how candidates can convey their platforms in the most effective and compelling ways".

But isn't there a danger that such information might foster unfair bias? Justin Berenbaum, a vice president at EmSense, would not discuss the possibility, saying: "Our work in politics is confidential and we therefore cannot participate."

The technology's military potential is also being developed. Researchers at Honeywell Aerospace have created an EEG system that reads defence analysts' brains as they examine spy-satellite photographs. Because our subconscious brains run significantly faster than our conscious neocortexes, a photo-analyst's brain can unconsciously register a visual anomaly long before they may become aware of it. Honeywell's brain scanner issues an alert when it detects neural signals that show the analyst has subconsciously noticed something suspect. Bob Smith, the company's chief of advanced technology, claims it will make spy-photo analysis up to six times faster, "helping the military keep threats out of harm's way".

But most commercial attention is fixed on the premise that brain-scanning can divine truth from falsehood. Dr Steven Laken, the founder of Cephos, a company using fMRI-based lie detection, says more than 300 people have already been tested in the company's scanner at Framingham, Massachusetts. Laken believes that American judges are on the verge of making scanning tests admissible – despite questions over their accuracy. "We tell people that the test is not 100 per cent. Studies have shown that we are between 78 and 97 per cent accurate. So long as you tell a jury that, it still can be considered as evidence."

The scans watch for giveaway brain patterns when people are under interrogation. Five years ago, fMRI researchers at Temple University, Philadelphia, found that we use different parts of our brains when lying: our cingulate gyrus, in the middle of the brain, lights up if we are being honest, but lying stimulates the limbic lobes, towards the forebrain. Lying also requires us to use more brain power. "Virtually all our clients want to show that they are telling the truth," Laken says. "One third are in some private family or work matter. About a third are civil or criminal. The other third are people who have been jailed and want to prove they are speaking the truth about their innocence.

"There are ethical things that we have to face," he acknowledges. "We would refuse anyone who wanted to bring their spouse in for a 'surprise' MRI scan while they were being asked about fidelity." But what if a paying client tests as guilty about some awful misdeed? "Not everyone who has come to us has proved their innocence. When we communicate the results to a client, they can say, 'Get rid of the data,' and we do. It's their data; it's up to them what happens to it."

With the help of American technology, Professor Sean Spence of Sheffield University has pioneered the use of brain-scan lie detection in Britain, employing the test on Susan Hamilton, 43. The Edinburgh mother was sentenced to four years in prison in 2003 for poisoning a child in her care with salt overdoses, but she maintains her innocence and is campaigning for the sentence to be repealed. Spence's study, published last year in European Psychiatry, reported that the scan was consistent with someone telling the truth. The results have not, however, been submitted as evidence to a British court.

Steven Laken claims that the technology can be developed far further – into a new discipline of "forensic brain-scanning" that examines people's intentions, goals and feelings. "Does someone understand that what they did was wrong, or did they intend to do it? This makes the difference between murder and manslaughter. We may also be able to tell if someone has been in a terrorist camp, or had certain motivations. For example, if you show someone a place they recognise, their brain reacts differently under fMRI than if they are seeing a picture of a place they never visited. With eyewitnesses, false memories light up different parts of the brain than true memories, which could be very useful for asking witnesses to identify criminals."

How soon can all this happen? "It depends on whether people want to commit money and resources," says Laken. "It could be done in 12 to 16 months if there were the government will. After all, we developed the atom bomb in less than four years."

The technology is constantly developing. A new superconducting material, doped rare earth iron oxyarsenides, may enable scientists to boost the magnetic fields that create an fMRI scan's sharpness and shrink the giant scanning machines to a portable size. Another imaging system under development, near-infrared spectroscopy, uses lasers to measure blood flow in the brain. It is non-invasive and may be carried in a suitcase, enabling investigators to interrogate people at home.

Joel Huizenga, chief executive of the boldly named No Lie MRI, says he has already applied for patents in America and Britain to use both fMRI and near-infrared scanning. He is negotiating to open facilities with UK companies that use scanners for medical applications. Huizenga's product does not stop at lie detection: "People want clarity over three topics: sex, power and money. We are using our systems to do 'Are you going to buy?' detection for advertisers, 'Do you recognise a face?' for police line-ups, and 'Are you in pain?' for compensation claims."

Despite all the bullish optimism, sceptics argue that much commercial brain scanning may prove more akin to brain scamming. Dr Lewis has been working in the field since the Eighties, when he says there was "commercially no interest in it at all". Now that neuroscience's tempting potential is becoming commonly understood, he says, entrepreneurs are offering products that race ahead of what is currently possible. "There are companies doing well-substantiated stuff with this technology, but there are also cowboys. There is speculation, there is speculation squared, and then there is neuroscience. The people who buy it are often too eager for the promises to be true."

Indeed, a research review published last December in *Perspectives on Psychological Science* condemned the scientific basis of half of the 54 peer-reviewed fMRI brain-scanning studies it covered. The review, conducted by the University of California at San Diego, concluded that 27 of the studies' statistical measures of brain activity were so poorly analysed that the findings were worthless.

Lewis adds: "The amount of light we have shone on the brain merely serves to show how much more darkness there is. You can scan the brain while it's experiencing something

and see certain areas light up, but correlation is not causation. When you scan someone's brain while they watch a Pepsi or Coke commercial, the conclusions you draw from the data can only be extraordinarily speculative. In terms of technology, we are just beyond the Wright brothers, flying around in a few flimsy biplanes. But often people are selling and buying the products as though they were jumbo jets."

John-Dylan Haynes is in the vanguard of scientific breakthroughs using fMRI scans to predict thoughts and actions. But he shares Lewis's fears and wants to see a vigorous debate on the technology's applications. Real advances continue to be made, he says, but a fundamental question remains: can they ever cut it in the brain-swirling world outside the laboratory?

"The science is so exciting that it is being picked up by commercial people who are vastly overselling its power," says Haynes. "There are companies offering lie detection, but I don't believe these techniques are operating at a level fit enough for a commercial service or a court of law. Even with sufficient funding, it will take ten to twenty years possibly to develop techniques that are close to a reliable universal lie detector.

"Our lab work on deciding a person's purchasing decisions has proved almost shockingly precise," he adds. "Even when people were not consciously thinking about what they were going to buy, we could detect the activity at a non-conscious level. But we can't say whether you can do that in the real world. Nevertheless, neuromarketing is being sold as a technology that is already available."

"Neuromarketing will always have ethical problems and I would always argue against using it," says Haynes. "In the academic world, brain-imaging institutes are very strong on data protection. But as soon as these practices become commercial? It's very worrying."

Hank Greely, a professor at Stanford Law School, sighs heavily as he considers how cod brain science may increasingly distort many court judgments. Greely is a pioneer of "neurolaw", and his faculty has been awarded a $10 million grant to explore the legal and ethical implications of neuroscientific advances. He cites the case of Aditi Sharma as a prime example of what can go wrong. "It stinks," he says. "The non lie-detection evidence was very weak. Then they threw in this 'science' as a trump card.

"We worry a lot that juries and judges are going to be way too impressed by fancy pictures of brain scans. But these are not photographs: they are computer-generated images of radio-wave information taken at a certain time and configured or manipulated in certain ways. Studies already show that people are more likely to give credence to a statement about the brain if it includes a picture of a brain scan, no matter how spurious it is."

Greely is keen to stress that he's no Luddite: "There may be some really good stuff that comes out of this technology," he says. "We just need to make sure we use it only when we are ready, and when we have decided that it is socially and ethically OK to use it.

“With lie detection, I think it may be OK to use it when someone wants to undergo it to prove their innocence. It’s much harder to think of forcing someone to take a test. I don’t think that your employer or your spouse should be able to make you take a lie-detector test, or that you should be able to subject your kids to one.” He pauses, then adds, “But you know, that parent example is a lot harder – particularly if you have teenagers who you fear are misusing dangerous drugs. It’s complicated.”

Perhaps a statutory right to “mental privacy” could help to set boundaries. This is a central aim of the Center for Cognitive Liberty and Ethics, an American organisation lobbying for laws to define the contents of a human skull as private property. Wrye Sententia, a thirtysomething creative-writing lecturer at the University of California, Davis, is one of the co-founders. She fears that the time is rapidly passing when legislation could be introduced to protect our inner selves from public scrutiny.

“In the American legal system, one benchmark for making a technology admissible as evidence is whether it is widely used. So the kind of ‘wish-fulfilment use’ we are seeing is dangerous. Once it has crossed the line and is used in court, then it is hard to step back,” she says. “The right to brain privacy will be very questionable once people have accepted the technology.”

Another challenge to mental-privacy campaigners is the “What have you got to hide?” refrain, adds Sententia: “You may look guilty through refusal. It is like having CCTV cameras tracking people all over the place. That is now widely accepted and understood.”

One hope is that the premature introduction of some commercial scanning techniques may prompt safeguards that pre-empt the emergence of seriously invasive technology. But Sententia says that public apathy and ignorance may mean that this chance is lost. “We are trying to get ahead of the cart in relation to the advent of these technologies, but it is very difficult to get traction on this issue. Am I optimistic? Well, it depends if you catch me on a good day.”