# The man who weighed thoughts

Can you measure brain activity using a simple balance? Simon Makin discovers the 19th-century scientist whose work may yet find its way into modern labs

IN A spacious laboratory littered with bizarre instruments, a bearded scientist tends to a man lying prone on a strange, see-sawing bed. Adjusting a valve here and a counterweight there, the scientist keeps on glancing at a wavering line unfolding on a revolving drum. If he is right, its undulations reflect the ebb and flow of the man's thoughts.

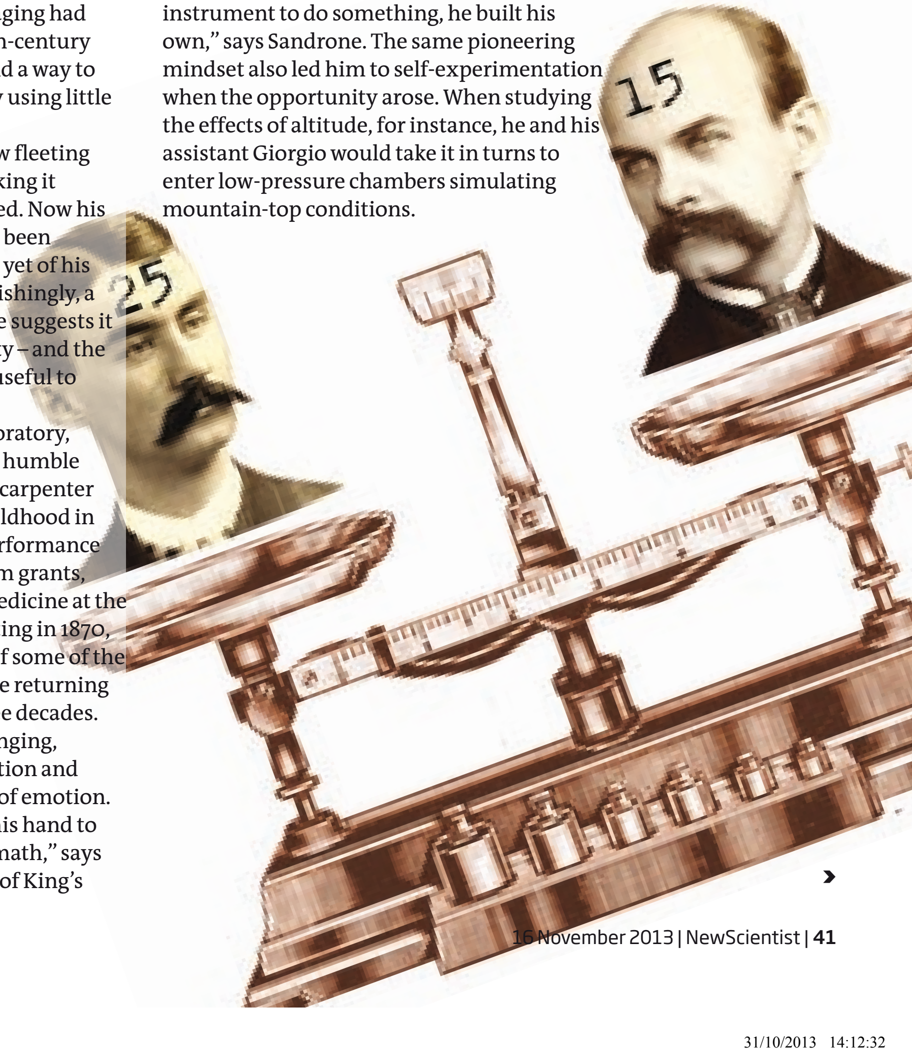
Angelo Mosso may have called his device a "machine to weigh the soul", but he had purely scientific interests. More than a century before modern brain imaging had taken the world by storm, the 19th-century physiologist had apparently found a way to measure changing neural activity using little more than a balance.

Until recently, we only had a few fleeting reports of the device to go by, making it difficult to know whether it worked. Now his original manuscripts have finally been unearthed, offering the best view yet of his ground-breaking research. Astonishingly, a modern re-creation of the balance suggests it really could measure brain activity – and the principles behind it could prove useful to today's neuroscientists.

As he laboured in his Turin laboratory, Mosso's life was a far cry from his humble origins. Born on 30 May 1846 to a carpenter and a seamstress, he spent his childhood in relative poverty. His academic performance was impressive enough to win him grants, though, enabling him to study medicine at the University of Turin. After graduating in 1870, he embarked on a five-year tour of some of the best laboratories in Europe, before returning to the university for the next three decades.

Mosso's interests were wide-ranging, covering everything from circulation and muscle fatigue to the physiology of emotion. In his final years he even turned his hand to archaeology. "He was a true polymath," says neuroscientist Stefano Sandrone of King's College London, who has written a biography of Mosso for the *Journal of Neurology* (vol 259, p 2513). "Eclectic, but not superficial, he deeply investigated everything he studied." Under Mosso's influence, Turin's school of physiology flourished, becoming a Mecca for some of the best Italian scientists of the era, and he was nominated for a Nobel prize.

Powering many of Mosso's enquiries were the practical skills he learned in his father's carpentry workshop. "If he didn't have an instrument to do something, he built his own," says Sandrone. The same pioneering mindset also led him to self-experimentation when the opportunity arose. When studying the effects of altitude, for instance, he and his assistant Giorgio would take it in turns to enter low-pressure chambers simulating mountain-top conditions.



"Mosso found that the balance tipped faster when his subjects read a philosophy text than when they read a newspaper or novel"

His daughter Mimi's book, *A Seeker of the Unknown*, contains a gripping account of one of these experiments: "All eyes were intent on the face of the man who by now had touched the zone where few living beings had ever risked…" After reaching the equivalent of 8000 metres – the peak of Everest – he gestured to stop and Giorgio sighed with relief and let the air back in. They opened the door, "and my father came out of his diving bell, staggering, he had to lean against the wall in order not to fall". Mosso incorrectly believed that altitude sickness was caused by low levels of carbon dioxide, not oxygen, and had only remained conscious because he had increased the oxygen concentration in the chamber.

Daring as these experiments were, it is his work on the brain that is of most interest to psychologists nowadays. Mosso was one of the first to believe that blood flow to the brain changes according to what we are thinking, with more rushing into the skull to fuel our neurons during a taxing task. A similar principle is now central to techniques such as fMRI, which measures the blood flow in and out of different regions to compare their relative activity. "Modern neuroimaging is linked to an old concept," says neuroscientist Marco Catani, also at King's College London. "You can't measure neural activity directly, but you can look at shadows, and one of these has always been changes in blood flow." But in Mosso's time it was controversial.

Mosso's initial approach was to examine people with skull defects that meant part of their brain wasn't covered by hard bone. He sealed a chamber filled with air around the skull, using a modified version of a device called a plethysmograph, and as blood rushed to and from the brain, the soft tissue pulsed up and down, displacing enough air from the chamber to register on a display. Mosso showed that when someone was given difficult calculations to perform, their brain pulsations grew larger. William James, one of the founders of modern psychology, called it "the best proof of the immediate afflux of blood to the brain during mental activity".

Such defects are rare, but Mosso also looked for ways to measure the same activity in people with intact skulls. The result was his "machine to weigh the soul". James's book *The Principles of Psychology* contained a fleeting account of the device, describing it as a "delicately balanced table" that tipped to the head when blood flow to the brain increased. But Mosso's own writings on the subject weren't widely reported and were soon lost meaning that it was difficult to know whether it worked as James said.

More than 100 years later, the idea nevertheless caught the imagination of David Field and Laura Inman at the University of Reading's Centre for Integrative Neuroscience and Neurodynamics in the UK, who decided to build a device based on James's account. Essentially, it was a lever: a participant lies down and the set-up is adjusted until their centre of gravity is directly over the fulcrum – making it respond to tiny shifts in weight as blood rushes to and from the head.

Field and Inman soon found their device was just too sensitive, always dropping down to one side. "The first thing you realise is this thing is never going to be level," says Field. To remedy the problem they let it tip slightly towards the head end, so that it rested on a set of electronic scales that also served to measure the subtle forces being exerted on the balance.

Having fixed one problem, the team then found that fluctuations from internal movements – such as breathing and the heartbeat – were skewing the readout. "That movement is much greater than any variation related to the brain," says Field. Their solution was to use a computer to subtract these signals from the forces recorded by their scales as their subjects experienced different sights and sounds. After careful analysis, they concluded that the weight of the brain really did increase with stimulation – although typically by a force of less than a hundredth of a newton.

So a brain balance could work, in principle. But had Mosso managed to overcome the challenges, or was he, as Field once suspected, a "fraud"? Answers wouldn't come until Sandrone, Catani and colleagues uncovered Mosso's manuscripts to publish a detailed account of his experiments earlier this year (*Brain*, DOI: 10.1093/brain/awt091). Seeing the paper, Field realised that Mosso had faced the same problems as him and Inman and had "tried to find 1870s solutions to them".

Unlike Field, Mosso had allowed his device to sway, and it was this see-sawing motion that led to the wobbly graph reflecting his subjects' thoughts. But to prevent it swaying too far either side, he had damped its motion with an adjustable counterweight hanging on the underside of the table (see diagram, left).

He had also found ways to take account of the commotion in other parts of the body, using adapted plethysmographs to measure pulse-related changes in a hand and foot, and breathing-related changes in the chest. Comparing all these with the movement of the balance allowed him to pick out the brain-related blood flow changes – in much the same way that Field accounted for variation in his own 21st-century version of the machine.

Sandrone's paper gives a translation of Mosso's accounts of his first experiments on Giorgio and a 22-year-old student. He reported, for instance that an alarming sound increased blood flow to the brain. In later experiments he also gave his subjects passages to read from a newspaper, a novel and a philosophy text, and reported that the balance tipped faster when they were reading the philosophy text – which is what you might expect for a more difficult activity.

## Trailblazer

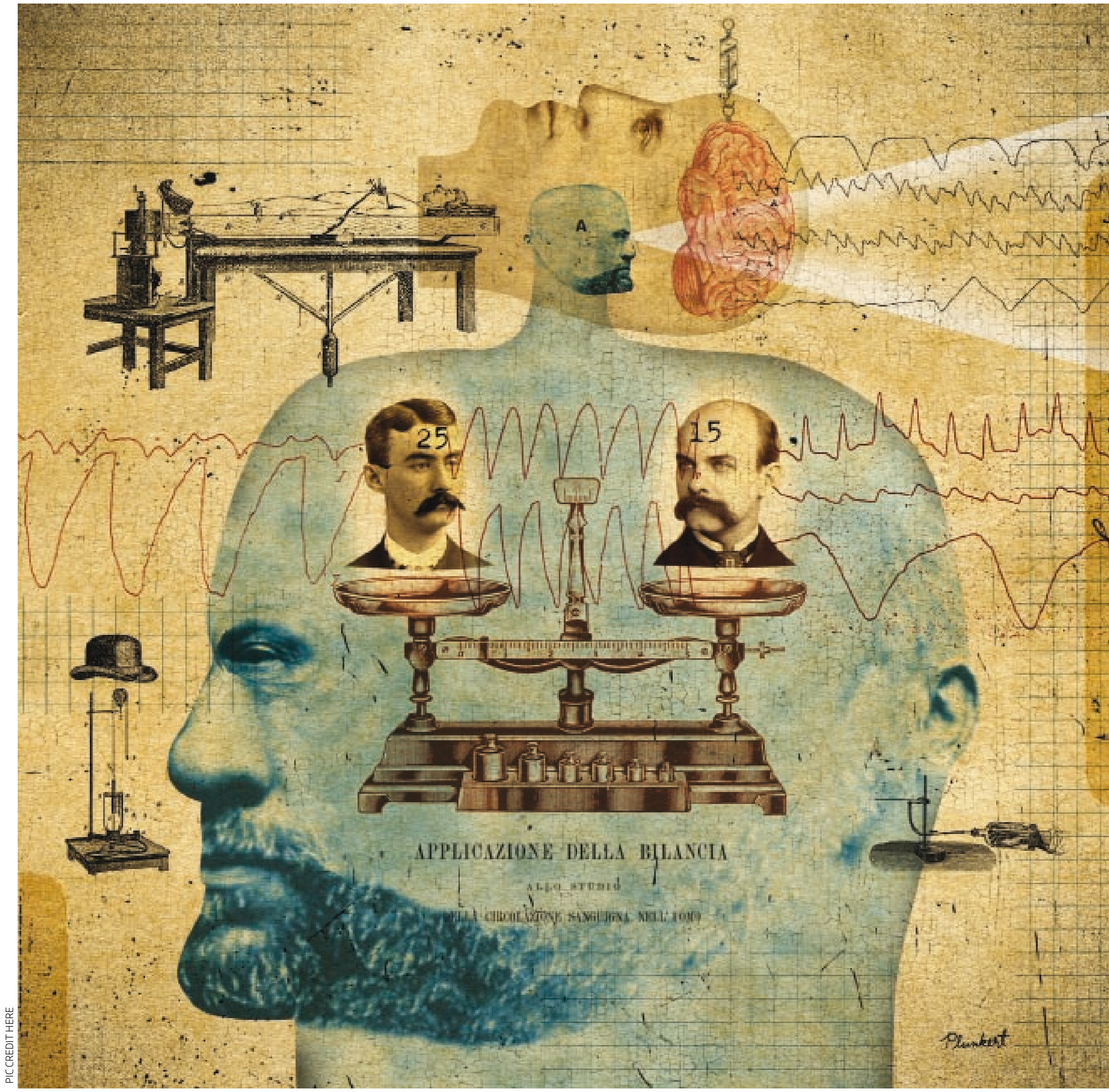
Despite these accounts, Sandrone and colleagues can't definitively confirm that Mosso's machine worked with any accuracy. "But that's probably not the question," says Sandrone. What's important was that Mosso was trailblazing the study of brain activity, while considering the kinds of questions that modern neuroimagers face today. For instance, scientists using fMRI still consider the fluctuations caused by the pulse and respiration, and they need to maximise the "signal-to-noise ratio" in much the same way Mosso did. It is also remarkable that Mosso was considering factors like age, sex, and education when coming to his conclusions, says Sandrone. He now hopes to organise an event around the balance, which resides at the Scientific and Technological Archives in Turin.

Intriguingly, despite its advances, modern neuroimaging might still have something to learn from Mosso. Field points out that by comparing the relative distribution of oxygenated and deoxygenated blood across different regions, fMRI allows you to see which areas are working harder. But unlike the balance, it can't reveal how the total volume of blood changes - so it can't say which of two situations requires the brain to work harder. The balance might also be useful when studying medicine. "Imagine you have a drug that might affect the volume of blood in the brain," says Field. "fMRI couldn't get a handle on that, whereas this technique could."

Field is also considering modifying the device to answer a different question. If the fulcrum ran lengthways, the balance might be able to measure differences in the activity of the brain's two hemispheres – which could help to settle questions about whether the "right brain" or "left brain" are more active during certain tasks. He doesn't know if this will work, but he's planning to find out. "What I've found from doing science for years is you don't know until you try it," he says.

Mosso would no doubt agree. As he tinkered away in his lab, he couldn't have imagined the advances that would follow his pioneering work – nor the lengths that people would go to re-establish its reputation. But the balance of history may finally be turning in favour of his soul-weighing machine. ■

Simon Makin is a writer based in London, UK




PIC CREDIT HERE

## The weight of thoughts