

Who we are

The field of neurosciences has expanded to study complex behaviour, motivation and decision-making. But social conclusions from this research should be made with caution

The French philosopher René Descartes' most important contribution to the natural sciences was his introduction of the concept of doubt. The process of gaining knowledge, he claimed, must start by doubting everything that seems factual. The only thing of which a person can ever be sure, Descartes said, is that he or she exists. Even the existence of the material world around a person could be an illusion. In his most famous statement, "*Cogito ergo sum*"—I think, therefore I am—he referred to an immaterial, thinking self. "'I', that is to say, the mind by which I am what I am, is wholly distinct from the body," he wrote. It is an ironic twist that modern neurosciences now doubt the existence of this immaterial 'mind'. There is no scientific evidence for a 'mind' or 'self' that exists independently of the body or brain. By contrast, it is the brain that causes thoughts, decisions and other traits that we attribute to the mind and to our free will. "I think that the statement 'not me, but my brain decided' is correct", said Gerhard Roth, a neuroscientist at the University of Bremen, Germany (Roth, 2004).

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This reduction of 'free will' or the 'self' to mere chemistry raises important questions for philosophers and psychologists, who must integrate knowledge of brain chemistry and neuronal processes when explaining human nature. The results of neuroscientific research have led to the emergence of fields such as neuroeconomics, neuromarketing, neurolinguistics, neuropsychology and neurotheology, and neuroscientists are now asked to offer their expertise on almost everything from the existence of God, to education and criminal justice.

In the past, natural scientists tried to explain behaviour and personality traits by measuring and weighing brains in search of

features that would explain intelligence or criminal behaviour. Why, after the failure of these attempts, has modern neuroscience moved the topic back into the spotlight? What new insights have restarted the discussion over free will? Why is the existence of a distinct soul or mind, for which scientific evidence is and has always been lacking, again under scrutiny?

The impetus behind this recurrent interest in our brain, and ultimately in human nature, is the enormous advances in molecular biology and imaging technology, which allow scientists to determine and analyse the neuronal basis of complex behaviour. Aspects, such as personality traits or decision-making, that—in a dualistic worldview where body and mind are distinct—were once attributed to an immaterial 'self', are now linked to neuronal activity. The neuronal correlates of our ability to distinguish self from others, and of sympathy, volition and conflict, have been established (Decety & Chaminade, 2003a,b; Zhu 2004; Rushworth *et al.*, 2005). The biochemical bases for trust and violence are being revealed (Kosfeld *et al.*, 2005; Nelson & Chiavegatto 2001), and a neuronal definition for forgiveness has been formulated (Clark, 2005). In addition, pharmaceutical research has produced drugs that influence mood or cognitive abilities, demonstrating the chemical contribution to personality traits—you may be a different 'you' while on Prozac®.

Moreover, various experiments to explain the process of decision-making have found

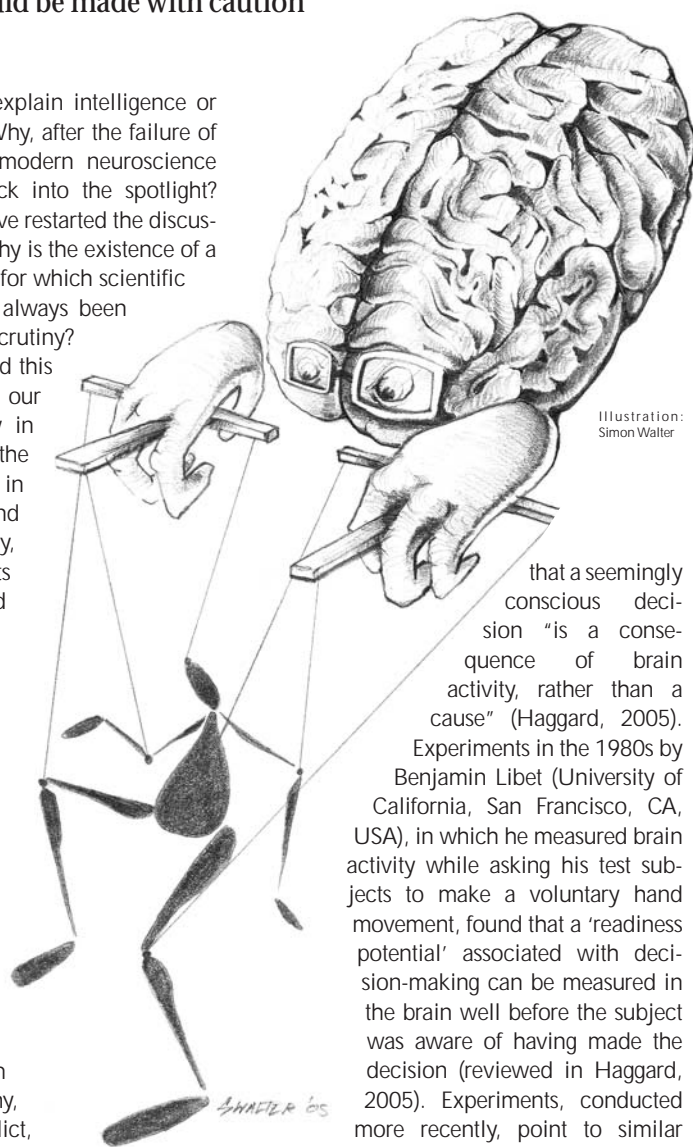


Illustration:
Simon Walter

that a seemingly conscious decision "is a consequence of brain activity, rather than a cause" (Haggard, 2005).

Experiments in the 1980s by Benjamin Libet (University of California, San Francisco, CA, USA), in which he measured brain activity while asking his test subjects to make a voluntary hand movement, found that a 'readiness potential' associated with decision-making can be measured in the brain well before the subject was aware of having made the decision (reviewed in Haggard, 2005). Experiments, conducted more recently, point to similar conclusions: intention follows behaviour, rather than causes it—we want what we do, rather than do what we want (Haggard, 2005). But because such interpretations do not necessarily apply to decisions that are more complex than a 'voluntary' hand movement, their consequences for human social behaviour are questionable.

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The fact that sympathy, volition and happiness may have neurological and chemical counterparts does not necessarily mean that our emotions and sensation of free will are an illusion. “Demonstrating that subjective emotional conditions are causally determined does not annihilate their existence” (Roth, 2003). But most humans are trapped in Descartes’ dualistic worldview, which treats matter and soul as two fundamentally different things. They therefore find it difficult to think of themselves as based in the brain, which is subject to the rules of physics, just like any material thing. In physics, everything is either predictable or, at the subatomic level, random. How then can free will emerge from a product of predictable and random processes? As human beings, we prefer to believe that we cause actions to be carried out by our brains, rather than being caused by them—we like to view ourselves as ‘uncaused causers’.

How ... can free will emerge from a product of predictable and random processes?

According to Joshua Greene, a psychologist at Princeton University (NJ, USA), the difficulties in getting to grips with this apparent contradiction may reflect two different ways of processing information in the brain, rather than an inherent separation of soul and body. “We have separate brain systems for dealing with different aspects of the world: a ‘folk-physics’ system that deals with the movement of objects, and a ‘folk-psychology’ system for dealing with minds, where we try to predict and understand behaviour in terms of beliefs and desires and intentions,” explained Greene. “Because those two systems are separate, we think that there are two fundamentally different things out there in the world even though there aren’t.” This biologically determined, dualistic worldview is enhanced by cultural tradition. It is prominently reflected in western philosophy in the ideas of Descartes, and almost every religion is based on the concept of an immaterial soul.

The question of whether free will is an illusion therefore depends on how it is defined. “Our conception of ourselves as being above the laws of nature in some sense—as being uncaused causers in a physical world—is an illusion, I think,” said Greene, “but we do have the ability to

produce voluntary choices that are a product of our desires and beliefs.” Steven Rose, head of the Brain & Behaviour Research Group at the Open University, UK, argues that this ability invokes an authentic moral agency (Rose, 2005). “Agency is our ability to decide and take action. That action is constrained and shaped by our biology and is constrained and shaped by the social context. We exist at the interface of multiple determinisms,” he said. “The way we act and we are is what we create ourselves of our raw material and our environment and our genetics.”

A more moderate definition of free will, which does not include an immaterial soul, is thus perfectly compatible with its determination by neuronal processes. This ‘compatibilist’ interpretation now predominates among contemporary philosophers and neuroscientists, but Greene and Jonathan Cohen, Professor of Psychology at Princeton University, doubt that it will prevail in the public realm, which is still largely married to the dualistic interpretation (Greene & Cohen, 2004). Popular media continues to convey the impression that ‘we’, as immaterial things, inhabit complex machines that control our actions.

It is here, at the interface between science and society, where problems arise. Obviously, the largest impact of a redefinition of free will would be on the legal system—without free will, there can be no guilt. The current legal system is based on the reasonable behaviour of people and their “capability of producing behaviours that serve their desires in light of their beliefs” (Greene & Cohen, 2004). As long as this minimal requirement is given—and a compatibilist would argue that there is no scientific evidence to contradict it—there is no conflict between law and science (Morse, 2004; Greene & Cohen, 2004). Traditionally, law is based on *mens rea*—the ‘guilty mind’—and it takes into account cases in which the requirement of guilt is not met. If a crime was carried out reflexively, in self-defence, in a state of diminished awareness, or under duress, the defendant’s control of rational argumentation is regarded as impaired, which is taken into account when passing sentence. Mental health is another factor that affects sentencing, as criminal liability is diminished in cases of insanity.

It is exactly this distinction between a voluntary and an involuntary act, between a healthy and an insane brain, that fuels debate

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over the impact of the neurosciences on criminal law. If every behaviour results from purely physical events—and is therefore subject to the laws of physics and impossible to influence by a voluntary act—every misdeed would have to be treated as an involuntary act. “A distinction between a physical, mechanical process on the one hand, and a true human choice on the other hand, is artificial”, said Greene. “Even true human choices are physical processes.” The brain, regardless of mental illness, causes all misdeeds. “In neuroscientific terms, no one person is more or less responsible than any other for actions,” wrote Michael Gazzaniga from Dartmouth College (Hanover, NH, USA; Gazzaniga, 2005). If modern neuroscience considers behaviour as being carried out ‘reflexively’—with an individual only becoming aware of the brain’s reflexes after it has made a decision, as the experiments of Libet and others would suggest—the idea of a ‘guilty mind’ would be obsolete. This does not mean that there should be no punishment—rather that punishment be carried out not to avenge, but to educate or to protect the population from a wrongly wired brain. Such an approach would have major consequences for criminal law. It could lead to improvements, such as more emphasis on rehabilitation, but it could also lead to penalties that are, at least by current standards, harsh and unjust.

Whether neuroscience is robust enough to distinguish between voluntary and involuntary acts, or between ill and healthy minds, is a central question for philosophers and legal experts. “It is an artificial distinction, it’s a pragmatic distinction, and although it may get a little frail and difficult at the edge, it’s a distinction I would want to retain,” said Rose. “If someone picks up someone else’s belonging and can’t remember, because he has Alzheimer’s disease, we need to look at the biochemistry of Alzheimer’s for an explanation. But it would be ridiculous to discuss the level of serotonin in the brains of the people who planted the bombs in the London underground or to understand the bombing of 100,000 civilians in Iraq by looking at what is going on in Mr. Bush’s or Mr. Blair’s brain. ... We have to look at the economic, political and social

circumstances [which led to those events]. You need to look in the right place, and looking at the brain is not always the right place."

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Looking in the right place has also proven difficult in the past. Scientific results and ideas about the morphological correlates of behavioural traits were repeatedly over-interpreted, but conclusions with considerable impact on society were drawn nonetheless. At the beginning of the nineteenth century, the German-French anatomist Franz Joseph Gall developed the field of phrenology—deducing personality traits from studying the shape of the skull—and claimed that this information should be taken into account when sentencing criminals. Some time later, the Italian anthropologist Cesare Lombroso argued that the 'born criminal' could be identified through physiognomic features, such as a large jaw, handle-shaped ears or fleshy lips. The German physician Oskar Vogt, best known for investigating Lenin's brain, also searched for personality traits in brain morphology. At the end of the Second World War, he unsuccessfully requested permission to examine the brains of Nazi criminals who were executed after the Nuremberg trials. Vogt hoped to find an explanation for the atrocities committed during the Nazi's reign of terror (Hagner, 2004), but probably would not have been very successful.

Today's scientific methods go far beyond measuring and weighing brains. Still, conclusions of socioeconomic relevance should be drawn with care. Popular media frequently produce articles that convey the impression that societal problems can be explained simply by neurology. Colourful magnetic resonance images from brains and other intriguing pictures add to peoples' beliefs in the limitless explanatory power of the neurosciences. One example of a story that could send the wrong message or confuse the public was an article in UK newspaper *The Guardian*, which described how neuronal reactions to black and white faces "may reveal brain's hidden centres of prejudice" (Adam, 2003). "The press is very good at interpreting things at that degree of crudity. This also applies to press releases put out by the university departments or by *Nature* or

Science when they want publicity for a particularly juicy paper," said Rose.

Despite the enormous advances that neuroscience has made over the past few decades, the field is still far from being able to understand the complex processes taking place in the human brain. Caution is therefore recommended when drawing conclusions of social relevance from such limited scientific knowledge, particularly when it comes to such central themes as the concept of guilt. This is not to say that neuroscientists should be prevented from commenting on social topics or the legal system. On the contrary, an interdisciplinary discourse can be very valuable. But they should exhibit a certain modesty when speaking about subjects, like the legal system, of which they know very little. "I think that, quite recently, there has been a tendency for some neuroscientists to speak outside their field of competence. I think most of us should shut up about consciousness and concentrate on the scientific questions that are amenable to our research," said Rose.

REFERENCES

- Adam D (2003) Inside the mind of a racist: scans may reveal brain's hidden centres of prejudice. *The Guardian*, Nov 17. www.guardian.co.uk
- Clark AJ (2005) Forgiveness: a neurological model. *Med Hypotheses* **65**: 649–654
- Decety J, Chaminade T (2003a) Neural correlates of feeling sympathy. *Neuropsychologia* **41**: 127–138

- Decety J, Chaminade T (2003b) When the self represents the other: a new cognitive neuroscience view on psychological identification. *Conscious Cogn* **12**: 577–596
- Gazzaniga MS (2005) *The Ethical Brain*. New York, NY, USA: Dana
- Greene J, Cohen J (2004) For the law, neuroscience changes nothing and everything. *Philos Trans R Soc Lond B Biol Sci* **359**: 1775–1785
- Haggard P (2005) Conscious intention and motor cognition. *Trends Cogn Sci* **9**: 290–295
- Hagner M (2004) Homo cerebrialis? *Frankfurter Allgemeine Zeitung*, Mar 22, p31. www.faz.de
- Kosfeld M, Heinrichs M, Zak PJ, Fischbacher U, Fehr E (2005) Oxytocin increases trust in humans. *Nature* **435**: 673–676
- Morse SJ (2004) New neuroscience, old problems. In Garland B (ed), *Neuroscience and the Law: Brain, Mind, and the Scales of Justice*, pp157–198. New York, NY, USA: Dana
- Nelson RJ, Chiavegatto S (2001) Molecular basis of aggression. *Trends Neurosci* **24**: 713–719
- Rose S (2005) *The 21st Century Brain: Explaining, Mending and Manipulating the Mind*. London, UK: Jonathan Cape
- Roth G (2003) Wir sind determiniert. *Frankfurter Allgemeine Zeitung*, Dec 1, p31. www.faz.de
- Roth G (2004) Worüber dürfen Hirnforscher reden – und in welcher Weise? *Dtsch Z Philos* **52**: 223–234
- Rushworth MF, Kennerley SW, Walton ME (2005) Cognitive neuroscience: resolving conflict in and over the medial frontal cortex. *Curr Biol* **15**: R54–R56
- Zhu J (2004) Locating volition. *Conscious Cogn* **13**: 302–322

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Think small

Lab-on-a-chip technology shrinks the biological laboratory to the micro scale and expands the potential for future applications

Small is beautiful. Just ask an engineer from the computer industry. Although the first computers in the 1940s and 1950s filled entire buildings, a contemporary Mac mini—barely larger than a stack of compact discs—performs the same tasks in a fraction of the time. The driving force behind this enormous increase in computing power and decrease in size was the invention of the microchip and its subsequent miniaturization, with even more transistors being packed onto even smaller chips.

The same process is about to affect biological and chemical research. The idea that all the components needed for an experiment could be miniaturized and packed on a single carrier system, which is smaller than a penny and able to handle the tiniest samples, is prompting efforts to create chips for the analysis of biological material. These 'lab-on-a-chip' analytical devices operate on the micro- and nanometre scale. In essence, it means that all the beakers, pipettes and other lab tools are shrunk to fit on a single chip about the