SCIENCE AND SOCIETY

Neuroscience and legal determination of criminal responsibility

Nigel Eastman and Colin Campbell

Abstract | Neuroscience is increasingly identifying associations between biology and violence that appear to offer courts evidence relevant to criminal responsibility. In addition, in a policy era of 'zero tolerance of risk', evidence of biological abnormality in some of those who are violent, or biological markers of violence, may be seized on as a possible basis for preventive detention in the interest of public safety. However, there is a mismatch between questions that the courts and society wish answered and those that neuroscience is capable of answering. This poses a risk to the proper exercise of justice and to civil liberties.

When the forensic psychiatrist for the Crown in the trial of Dennis Nilsen, a serial killer of homosexual men who was pleading 'diminished responsibility', was asked in evidence whether the defendant had an 'abnormality of mind' he responded that he was (merely) statistically abnormal[1]. Another expert, a psychoanalyst, said that of course he did, and described the abnormality in detail. A third responded, "it depends what you mean by abnormal". Meanwhile, to many, the nature of the defendant's offending behaviour itself suggested that the man must be not just statistically abnormal but also pathologically so[2]. But what if it could have been shown that Nilsen's brain was abnormal, different from the brains of those of us not prone to such criminal behaviour? Would that not have clinched the issue?

As description of the biology of some perpetrators of violence becomes increasingly sophisticated, it seems almost inevitable that courts will wish to incorporate such knowledge — both about defendants' criminal responsibility and their risk of re-offending — into their deliberations. Defence lawyers are especially likely to wish to draw on scientific knowledge such as this to attempt to demonstrate that particular defendants are both abnormal and not (fully) responsible for their actions — 'it wasn't me, it was my brain'. At the same time, the UK government is increasingly pursuing new laws towards preventive detention of those deemed to express 'dangerous and severe personality disorder' (DSPD), while there is law in many US states permitting such detention of 'sexual predators'. The search for a scientific explanation of offending expresses our civilized incredulity that 'normal people' might commit horrendous, therefore surely abnormal, offences. However, even if science does develop to show correlations of particular genes, or types of brain state, with aggression, will that necessarily infer diminished or absent moral or criminal culpability?

In this article we therefore pose two separate questions. First, can biological correlates of violence be identified, and 'causation' (to use a legal term) be established? Second, do any such correlates infer absent, or at least reduced, moral and/or legal culpability? A related question is: if a person's genes or abnormal brain are associated with them being violent, then, irrespective of the implications for their moral or legal culpability, is not such abnormality a proper basis on which to effect their preventive detention in the interest of public protection?

Each of the two questions relating to culpability is profoundly problematic to address, although in very different ways. The first is scientifically difficult. For example, can we adequately define the nature of a behaviour that we might wish to suggest is associated with given biological features? Scientifically, can we go straight from brain to behaviour, or do we have to pass through psychology and 'personality type', or medical diagnosis of personality disorder, *en route*? Is not violence contextual, and its perpetration therefore determined by a combination of both trait and state features in the perpetrator, and environmental circumstance? Is not all violence, in a sense, provoked, not legally but in reality?

The second question is difficult in a different way. Addressing moral or legal responsibility (which are obviously distinct) might depend on scientific data, but requires entry to very different conceptual domains. Although demonstrating that a particular manner of brain functioning is associated with violent behaviour might be determined to be a pre-requisite for showing diminished or absent culpability, it could not be sufficient. The brain might be in particular states when its owner is violent, but what is cause and what is effect? Similarly, what is cause and what is mediation (by the brain)? Such questions draw us into fundamental questions of philosophy, of Cartesian dualism versus scientific determinism, or alternatively 'compatibilism'. Also, by inference, would it be right to exclude from diminished culpability those with apparent mental abnormalities but no demonstrable (perhaps as yet) structural or functional brain abnormality? As the law in England and Wales, as well as in most other common law jurisdictions such as the United States, currently stands, quite clearly not, as brain abnormality is not a necessary condition for determining diminished or absent culpability. There are routes other than the organic one to such a legal result.

So, must we ignore increasing evidence of associations between biology and violence because it raises difficult questions? In this article, we argue that the difficulty can at least be reduced by limiting enquiry

to the consideration of solely the legal, not the moral, relevance of such evidence. That is, to how the law responds, or is capable of responding, to increasing evidence of biological correlations with violence, addressing questions that are framed in terms of legal 'reductions', which necessarily fall far short of philosophical inquiry. However, we conclude that law, by its nature and process, may be incapable of acknowledging scientific evidence without, at best, misunderstanding such evidence, and, at worst, distorting it. Put simply, the law asks questions science is unlikely to be able to answer; whereas science answers questions that the law mostly does not pose.

Relationship between science and law

Law is ultimately pragmatic. It directly addresses difficult moral questions on the basis that it must somehow offer answers, derived and expressed in its own terms. In so doing, law has a natural inclination to both seek assistance from science and be sceptical of it. Its scepticism arises from the different social functions of law compared with science, and from the particular constructs, aimed at its own purposes, that it therefore derives for itself. These are very different from the constructs derived by science for its purposes. Therefore, law pursues the abstract idea of justice, which is arrived at through the adoption of legal artifices, whereas science attempts to describe and, ultimately, explain real phenomena observed to be 'in being'. Yet, at a lower level, law does deal with real circumstances and events, and so cannot avoid recourse to evidence, including scientific evidence. Such evidence ultimately serves the higher purpose of establishing abstract justice, and herein lies the source of the problem for law in relation to science, and the problem for science in being properly represented in legal domains.

In attempting to incorporate science evidentially, law has an inherent tendency to distort the science it thereby admits as evidence[3]. This is because there is no clear separation between justice and evidence. Decisions about what evidence is 'admissible' in a trial, and in what form, are both reflective and determining of the idea of justice adopted in the branch of law at hand. Therefore, even what is accepted as 'mental disorder' varies between different branches of law addressing distinct justice issues. For example, the various definitions of mental disorder adopted for the purpose of potential criminal exculpation are very different from those adopted in order to determine the justice, or lack thereof, of preventive detention, or in relation to various civil incapacities. In law, there is no such thing as 'real' mental disorder, only definitions of it that are adopted for purposes that usually have nothing to do with medical constructions of mental disorder *per se.* That is, law is 'autopoietic'. It can create only from within itself and within its own discourse[3]; therefore it is 'non-reflexive' to all other discourses, including that of natural science.

There are some branches of science, however, in which the mismatch with law is often masked, and neuroscience experiences particular difficulty in this respect. Neuroscience is interested in aspects of human functioning that appear to be 'close cousins' of matters in which the law is itself centrally interested. For example, neuroscientists are interested in 'thinking' and 'emotion', whereas law is interested in 'intention' and 'guilt'. Therefore, neuroscience addresses some issues that are 'close to' the ultimate issues with which the law is concerned. Unlike the forensic pathologist, who offers evidence that merely contributes to a factual finding that the law then 'uses' towards determining some ultimate issue, the forensic psychiatrist offers evidence that can come close to commenting on whether the defendant had the required intention for the crime of which he or she is accused. Put another way, much science offered as evidence assists in determining whether the defendant performed the *actus reus* (wrongful act), whereas behavioural neuroscience often assists towards determining whether or not the defendant had the required *mens rea* (guilty intention) for the act he committed (if he did commit the act). Ultimately, however, each discipline derives its own constructs from its own discourse, so that there can never be anything other than apparent, not real, similarity between them. This is reflected in the legal rule of evidence that not even an expert witness, who can otherwise uniquely give evidence of opinion, can comment on the 'ultimate legal issue'[4].

A further implication of the association between the interests of law and neuro science is that there is a high risk of neuroscience being sucked into heavily influencing, or even effectively making, decisions that are legal rather than medical, be they related to culpability, public protection or punishment, and especially so where law abandons its 'non-reflexive' nature[5]. That is, there is a risk of even the courts not properly maintaining the boundary between scientific evidence and legal decision.

Neuroscience and antisocial behaviour

Historical context. The current resurgence of neurobiological research on aggression has developed in the context of a growing contribution of neuroscience to the general understanding of complex behavioural traits, and is coincidental with violence being increasingly identified as a major international public health problem. However, efforts to understand aggression from a biological perspective have a troubled history, evoking images of the Italian school of criminal anthropology[6], as well as of the eugenics movement and the misappropriation of biology to provide a rationale for oppressive social policies[7].

During the past decade, biological evidence has accrued from various neuroscientific disciplines, ranging from neuroendocrinology[8,9] to psychophysiology[10], with many seemingly disparate findings being incorporated into unifying models of aggression, most notably in the emerging field of affective neuroscience[11]. However, two areas of research have dominated the literature — behavioural genetics and neuroimaging. Although attempts have been made to argue that genes make the man[12,13,14,15], it is evidence from the latter discipline that seems most capable of firing the imagination of the criminal justice system for its potential utility in the courtroom. In this article, we therefore concentrate on neuroimaging findings. In any event, many of the issues that arise in relation to neuroimaging also occur in the realm of genetics (BOX 1).

'Imaging' violence. Numerous studies have identified associations between structure and function of the brain and various indices of antisocial behaviour, using a range of neuroimaging techniques.

Authors of structural neuroimaging studies of antisocial individuals have reported increased callosal white matter[16], decreased prefrontal grey matter[17] and decreased posterior hippocampal volume[18]. However, as yet, none of these findings has been replicated, and it would be premature to draw any firm conclusions from structural imaging studies.

By contrast, functional neuroimaging in antisocial individuals strongly suggests that they have dysfunction of the frontal and temporal lobes. Positron emission tomography (PET) studies have shown associations between reduced metabolism in the frontal cortex and a history of repetitive violent behaviour[19], a life history of aggression[20] and having committed murder[21]. Reduced frontal perfusion has been described in antisocial individuals studied using single

photon emission computed tomography (SPECT)[22,23]. Abnormalities of frontal activation have been described using functional MRI (fMRI) during tasks assessing response inhibition[24] and the processing of emotional stimuli[25]. Differences in activation in the temporal lobes of criminal psychopaths and control subjects have also been demonstrated using fMRI during tasks that assess the processing of emotional words[26] (FIG. 1) and emotionally laden pictures[25] (FIG. 2). Nevertheless, despite the apparently convergent data, further studies are needed to replicate these findings.

So, although the early evidence from neuroimaging studies in 'psychopathy' is promising, it is far from conclusive. This might seem reason enough to be cautious about using such evidence in court. However, there are more fundamental methodological issues concerning neuroimaging studies of antisocial individuals that pose a substantial obstacle to its use in relation to important legal questions. Indeed, it is methodological inconsistencies between the studies that underlie, in part, the failure to replicate findings in the field[27]. Therefore, existing studies have used varying technical equipment and imaging modalities that reflect different physiological events, and tasks that tap into a range of cognitive processes assumed to be abnormal in antisocial individuals. The experimental populations are also extremely varied, ranging from those with a specific score on the Hare Psychopathy Checklist-Revised (PCL-R)[28], the accepted psychological measure of psychopathy, to accused murderers, to those with a history of violence. The choice of control group has been equally varied, and it has proved extremely problematic to control for even the most obvious of potential confounders.

More widely encountered methodological problems in neuroimaging are also of relevance. Neuroimaging studies, whether structural or functional, rely on a comparison between the experimental image and a normative template. The idea of such a template is itself problematic, and raises a number of issues that might impact on the ultimate interpretation of the data[29]. No gold standard exists, nor is there a consensus on which particular measure should be used as a normative standard, with the result that, in theory, any given brain might qualify as 'normal' on one measure but not on another. And, although the resulting image is often visually persuasive to an untrained audience, for example, a jury, an image from an exemplary study is indistinguishable from one from a poorly designed study (see below).

The interpretation of functional imaging can be particularly problematic. As Canli and Amin[29] point out, an activation pattern is defined by a threshold for statistical significance, which is set by convention rather than as an absolute standard. As such, it represents a statistical interpretation of a complex data set, which might be interpreted differently by different researchers. The selection of test and control conditions is also crucial, as different control conditions might produce different activation patterns during assessment with the same task. For example, the idea that rest is a zero activity condition has been challenged, and brain regions that do not appear to be involved in a task when rest is used as a baseline might be significantly activated if an alternative baseline is used[30].

Two broader points are also of particular relevance to the application of neuroimaging findings in criminal proceedings. First, neuroimaging identifies an association between two variables, and causality (or, indeed, its direction) cannot be assumed. Second, so far there is no evidence that neuroimaging findings in relation to antisocial behaviour have any predictive validity. And, even if these significant problems could be addressed, there would remain the fundamental problem already described concerning the extent to which legal constructs, such as intent and responsibility, approximate the cognitive

Box 1 | **Behavioural genetics and antisocial behaviour**

Behavioural genetics is already influencing the accepted ideas of legal and moral responsibility in court. Perhaps the most widely cited case in which defence lawyers used genetic factors in the defence of their client is that of Stephen Mobley[12,13,14,15]. Mobley shot dead a pizza store manager in the United States in 1991. Citing research by Brunner *et al.*[42], which identified an association between a point mutation in the monoamine oxidase A (*MAOA*) gene and antisocial behaviour in a large Dutch kindred, Mobley's lawyers requested that he be tested for this genetic abnormality. They argued, unsuccessfully, that this might explain his actions in an effort to save him from imposition of the death sentence. The judge stated that the law was not ready to accept such evidence, and Mobley's father subsequently sacked his son's lawyers, perhaps mindful of the potential implications of any positive genetic findings for the rest of his family. Mobley was executed by the State of Georgia on the 1st of March 2005.

Quantitative genetic studies have continued to provide a strong case for the importance of genetic factors in antisocial behaviour. In a recent meta-analysis of 51 twin and adoption studies, Rhee and Waldman[43] estimated that ~40% of the variation in adolescent and adult antisocial behaviour can be accounted for by genetic factors.

The candidate gene approach has yielded meagre but promising results. MAOA metabolizes monoamine neurotransmitters, such as 5-hydroxytryptamine (5-HT, or serotonin), noradrenaline and dopamine, and deficiencies in MAOA activity have been linked with aggression in both mice and humans. Caspi *et al.*[44] found evidence for a gene–environment interaction such that a functional polymorphism in *MAOA* moderated the effect of early childhood maltreatment on the development of antisocial behaviour in men. This finding has recently been replicated in a large community-based sample of male twins[45].

Another approach that has been used with some success is the study of animal models[46]. In particular, targeted gene disruption techniques in mice can help us to identify genes that affect aggression[47]. One such example is mice with targeted disruption of neuronal nitric oxide synthase ($nNOS^{-/-}$). These mice show dramatic increases in aggressive behaviour[48] and, significantly, given the evidence linking 5-HT to aggression, Chiavegatto *et al.*[49] found that the excess aggression and impulsivity seen in $nNOS^{-/-}$ mice is caused by selective decrements in 5-HT turnover and deficient $5\text{-}HT_{1A}$ and $5\text{-}HT_{1B}$ receptor functioning in brain regions that regulate emotion.

Although the emerging evidence for the role of genetic factors in antisocial behaviour is promising, there remain a number of methodological problems that seriously limit their utility in the courtroom. As with neuroimaging studies, definition of the phenotype under scrutiny is problematic, as is the inference of causality from any observed association. The question remains of whether, given the complex interaction of genetic and environmental factors in the aetiology of antisocial behaviour, it will ever be possible to present genetic evidence to a court in such a way that it meaningfully informs questions about legal constructs such as responsibility. Although in some cases gene–environment interactions have been elucidated, given the almost limitless number of possible interactions, will it ever be possible to quantify the contribution of perhaps one or two factors, in some sort of threshold model, to determine 'diminished responsibility'? An additional level of complexity, which might prove insurmountable, is that of temporal variation in the effect of environmental factors on any underlying genetic predisposition. That is, the nature of the current stimulus and its significance or meaning to the individual, which may vary drastically from any specific point in time to another.

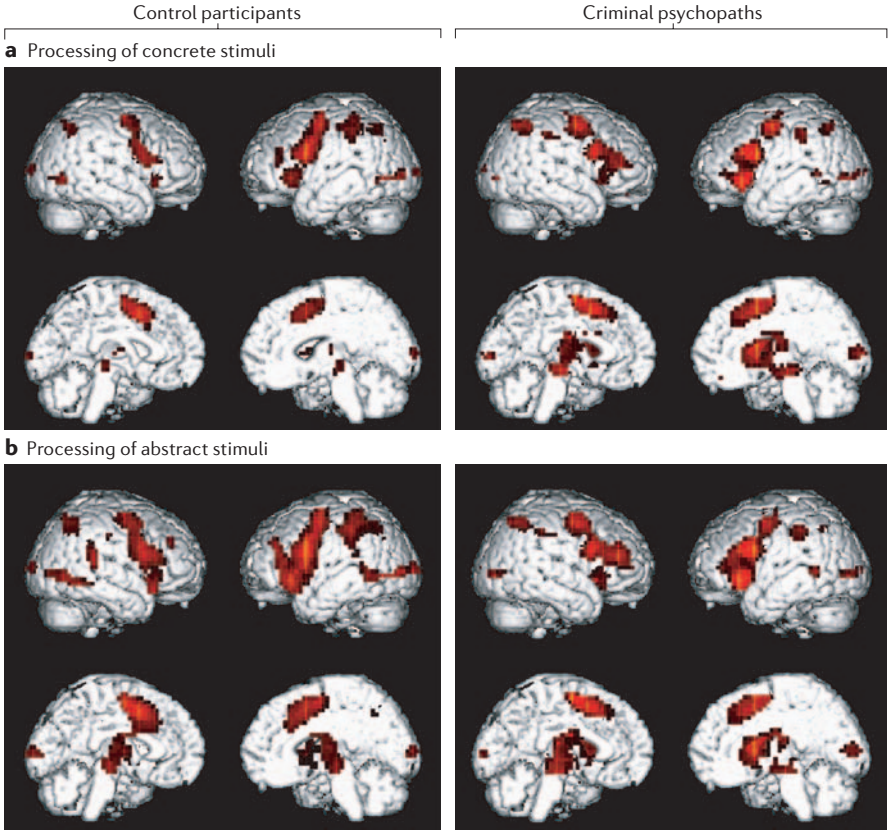

Figure 1 | **Different patterns of brain activation in criminal pyschopaths and control subjects.** **a** | Cortical surface rendering of the different areas in which control participants and criminal psychopaths show significantly greater activation for processing of concrete stimuli relative to baseline. **b** | Cortical surface rendering of the different areas in which control participants and criminal psychopaths show significantly greater activation for processing of abstract stimuli relative to baseline. Although visually compelling, the interpretation of such images is problematic. Modified, with permission, from REF. 26 © (2004) Elsevier Science.

constructs that have been investigated biologically, much less the images from which the cognition in question is inferred.

Is good scientific evidence enough?

Even if the methodological problems outlined above could be addressed to the satisfaction of both scientists and the courts, and a more robust evidence base developed, the broader social context in which such factors are invoked will remain. As Bostock and Adshead[31] point out, for example, in relation to genes, invoking even a contribution from genes as explanatory of antisocial behaviour can be understood as a political strategy that locates social adversity in the individual, obviating the need for any political approach to remedying rule-breaking and inequality. In a culture of social fear, in which public protection from risk tops the political agenda[32], good quality legal and moral reasoning might come under threat. Similarly, the interest of the legal profession in the neuroscience of antisocial behaviour has not arisen in a vacuum[7], and the scientific community, scientific journals and the popular media all have a role in accurately portraying the significance of research in this field and in avoiding misrepresentation of both the science and its social implications.

It is clear, therefore, that there are several points in the journey from brain image or gene to meaningful, admissible legal evidence at which the translation from science to law may go awry. Is the legally relevant research question being asked? Is the methodology capable of answering the question in a scientifically robust way? And, crucially, do the constructs investigated in the studies have any direct relevance to the legal questions they are expected to inform? So, even if there are associations between biology and behaviour, what are the legal implications? Alternatively, could not such evidence be used legally to point in two opposite directions? Supposing an individual has genes that influence (or, indeed, a neuroimage that reflects) the likelihood of engagement in criminal behaviour. It could be argued that, as they are unable to change their behaviour, they are in some sense compelled and, as such, are not responsible for their actions. Alternatively, those who are at greater genetic risk of antisocial behaviour could be seen as more responsible for their actions, particularly if they fail to make use of the tests, interventions or preventative measures available[31]. Certainly, one implication might be preventive detention by way of neuroscience.

Miscommunication

So, can neuroscience offer any valid assistance to criminal law? A criminal legal 'wish list' of questions that the courts might hope neuroscience could help them towards answering might include the following examples. Can genetics or neuroimaging studies predict violence or sexual offending; or suggest forms of 'treatment' to reduce the likelihood or degree of violence of a potential perpetrator? Can they predict a defendant's 'treatability'; or assist in determining whether he/she is lying[33], or is expressing a 'false memory'? Can they determine the degree to which urges are 'resistible', or otherwise assist in determining the level of responsibility of a perpetrator; or inform whether a defendant 'intended' to do what he did? Boiling these questions down, they fall into two broad domains, 'determining guilt' and 'predicting and preventing re-offending'.

Partly because law is ambivalent about science, it guards its own domains jealously. Therefore, in describing any likely abnormality of the defendant's mental state at the time of commission of the *actus*, for example, strictly, in law, psychiatrists may not state whether or not this substantially impaired the defendant's mental responsibility for his/her actions. And that restriction reflects the thesis of this paper, which is that law and science do not mix, and properly do not do so. That is, science describes things in being, while law applies artifices to determine abstract justice. Therefore, the 'answers' given by science are not answers to questions posed by law. Psychiatry, or neuroscience, may be able to describe abnormalities of mental functioning, in their own terms, but that is not to answer questions about legal responsibility. Scientific explanation is just that, and legal attribution of mental responsibility is also just that. And to attempt to go from 'science about things in being' to 'law in the abstract', which makes its own stab at answering what are ultimately profoundly difficult moral questions,

involves a journey for which there is no map, and which may not even 'exist' as a journey.

Despite this, the courts repeatedly seek help from science. And in so doing they ask legal questions on the clear assumption that the answers they will receive from science will validly assist in answering those questions, and without distortion of the science it thereby adopts as evidence. However, there is reason to be sceptical about this assumption, both because simple miscommunication commonly occurs when scientific answers are given to legal questions and, more substantively, because of the inherent 'mismatch' between legal questions and scientific answers.

It might seem that miscommunication leading to misunderstanding could only arise through careless failure of either — or both — the expert and court to achieve a proper transfer of knowledge from one to the other. However, it is unwise to assume that each side would necessarily even notice such miscommunication, given that the law does not inherently, within its own discourse, 'understand' science, and that science, within its discourse, does not 'understand' the law. Indeed, recent experience of expert paediatric evidence in criminal trials of mothers accused of killing their babies would seem to suggest the point.

Taking criminal sentencing as a legal example, there are increasing legal provisions that allow a court to impose a sentence not on a merely 'retributive' basis (the punishment fits the crime), or for reasons of rehabilitation or deterrence (of others), but for the purpose of public protection. This shift towards 'release based on risk assessment' has obvious potential implications for neuroscientists and criminologists (each applying different methodologies). Of course, the courts have their own way of assessing whether a risk-based sentence should be imposed. However, scientists clearly have a potential role in determining whether or not such a sentence should be imposed if there is mental disorder and a related reason to be concerned about risk in an individual, as well as potential involvement 'at the other end' when the Parole Board has to consider whether it is 'safe to release' the individual. Although the judges might be expected to be close guardians of their responsibility for justice in sentencing, there is reason to suspect that, faced with a defendant with a medically diagnosed 'mental disorder', judges might be inclined to be heavily influenced in their decisions by 'experts'. The most recent past Lord Chief Justice of England, Lord Woolf, said to a national conference of forensic psychiatrists in 2001, "When it comes to risk, we very much rely on you"[34]. Here, the law — or at least the courts — is reflexive.

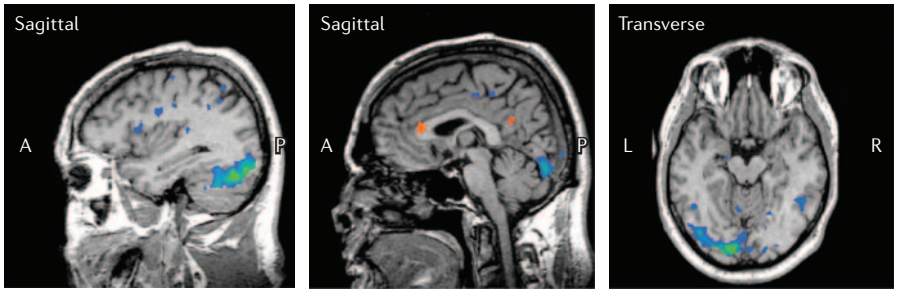

Figure 2 | **Differences in processing of negative emotions.** Regions of interest showing significantly increased activation (blue) in psychopathy compared with control subjects (red). Note the overactivation of the prefrontal cortex (sagittal view) and right amygdala (transverse view) in psychopaths. Underactivation was observed in the subgenual cingulate (sagittal view, depicted in red). A, anterior; P, posterior; R, right; L, left. Modified, with permission, from REF. 25 © (2003) Elsevier Science.

So, what sort of risk related statements is a neuroscientist or criminologist likely to give to a court or Parole Board, and might they be misunderstood? Although clearly based on different scientific foundations, they are each likely to give answers based on the idea of there being an association of violence with factors occurring in a population. Therefore, a scientifically valid statement might be, 'a man such as the defendant, with his characteristics (either social, developmental or biological), is a member of a class of people in which x% will offend in 'y' manner within 't' time'. However, it is all too easy to see how this might be presented, or understood, loosely as 'there is an x% chance of re-offending' — the error being that it is presumed that this particular individual, rather than a class of similar individuals of which he is a member, has an x% chance of re-offending in the described manner and timescale. So the law might be erroneously reflexive.

Of course, such an aggregate approach runs fundamentally counter to the law's 'individual' approach to justice. Therefore, defendants are not sentenced on the basis of their being a member of a class of individuals with given probabilities of offending in particular ways, but on the basis of what they have done and who they are. And this implies that the criminologist or epidemiologist can, and should, never help.

But surely the neuroscientist is in a different position? Surely he can tell the court something about who the defendant is biologically? Here almost exactly the same problem emerges. Except in certain very clearly defined and clinically well-understood situations, such as, for example, injury or disease to particular parts of the brain known to be associated with a lowered threshold to violence 'in almost anyone', the available evidence linking brain function with aggression is expressed in terms of populations and associations. Here, we are not dealing with someone who was non-violent before he or she had sustained brain damage and became violent thereafter, but with individuals who are 'constitutionally' violent, purportedly because of biological rather than psychological or social factors. However, the evidence that is available is written in terms of a recognized higher likelihood of violence in a population of people with given biological characteristics. As with criminological evidence, nothing meaningful can be said about a particular individual, only about a person in terms of his membership of a class of individuals with similar characteristics.

Despite all these difficulties, scientists can get drawn (or perhaps seduced) into 'trying to help with answers', especially when they fail to realise that the journey is impossible, or at least that 'translation' of their science automatically involves distortion. And this gives rise to a set of ethical questions for experts, in terms of whether they should give evidence when they know that it is likely to be distorted by court method; or whether that is merely a matter for the courts and not the expert.

Mismatch

Legally, 'association' should be irrelevant to the determination of sentence, even when sentencing is based on risk assessment, or when the sentence imposed is 'prison until shown to be low risk'. But the next stage in scientific inquiry after the discovery of association is the attempt to discover

Box 2 | **Criminal legal defences in the United Kingdom**

Automatism

Automatism (either 'sane' or 'insane') is the ultimate mental condition defence, claiming that the person's mind did not 'go with' their actions[50], or that their actions were not even 'actions' at all, because they were not 'willed'. The classic biological example of automatism is offending during or around an epileptic fit, although the law allows 'non-organic' automatisms, such as hysterical fugue. Whether evidence concerning 'genes and violence', let alone 'brain mapping and violence', will ever come close to satisfying the legal definition of automatism is highly doubtful. Even in the case of epilepsy, the person does not necessarily operate without any external influence upon their actions, because undefined external triggers could be responsible for epileptic fits. With regard to genes, the evidence is merely in favour of predisposition.

Insanity

If a person suffered from a 'defect of reason' at the time of the offence resulting from a 'disease of the mind' such that he either 'did not know the nature or quality of his action', or did not know that it was 'legally wrong', then he can be found 'not guilty by reason of insanity'[51]. In this case, the mind is operating and the actions are willed, but there is 'mad reasoning'. Although some gross clinical brain abnormality might imply insanity, possession of a gene that merely predisposed the defendant to act in the way that he did would be unlikely to satisfy the criteria. First, the gene might not express itself in cognition of a type so as to fulfil the legal criteria. Second, predisposition is 'not enough' for biological determinism, were that to be the test, as there must be other factors, within or external to the defendant, that operated on his genetic vulnerability towards offending. And, in any event, there is no necessary reliance on biological determinism on the part of the law in relation to either the defence of insanity or automatism.

Diminished responsibility

Genetic predisposition, or abnormal brain function, could be relevant to the partial defence of diminished responsibility. This allows a jury to reduce murder to manslaughter if the defendant suffered from some 'abnormality of mind' such as to 'substantially impair his mental responsibility for his actions'[52]. The defence can incorporate almost any sort of diagnosed mental condition, be it organic or functional. It can also allow for 'external factors' to operate upon the mental abnormality so as to cause the offence to occur; while separate factors, including even alcohol[35], may contribute to the offence so long as the mental abnormality was itself 'more than trivially' to impair the defendant's mental responsibility[53]. In this case, genetic evidence seems at least potentially more useful to the adventurous defence lawyer. However, again, this could only be used when there is evidence 'in the individual' of a genetic predisposition to violent behaviour, not merely an observed association between genotype and predisposition to violence in a group of genetically similar individuals. And the abnormality in the individual would probably need to be a phenotypic and not merely genotypic entity.

Provocation

This defence allows the objective 'reasonable man' with the '(mental) characteristics' of the defendant[54–56] to 'lose mastery over his mind'[57] in response to provocation, such that he is guilty only of manslaughter in killing the victim. However, the mental characteristics cannot be 'proneness to violence'[58] but must be characteristics that made the defendant more susceptible to the particular provocation emitted. This seems infertile ground for neuroscientific evidence.

a 'mechanism' underlying the identified association. If that can be identified, the relationship between science and law shifts somewhat. This is because the law does take account of mechanisms in determining, for example, the level of predicted risk posed by an individual. And, in relation to this, the establishment of a mechanism 'personalizes' the evidence, which is no longer expressed in terms of 'increased likelihood in a population' but 'increased likelihood in this individual' (because of the identified mechanism operating in the individual in question).

In choosing between using an expert opinion expressed in terms of 'psychological understanding' of a defendant and using biological evidence even suggesting that a mechanism underlies an observed association in a population, a court is likely to veer strongly in favour of the former. Such an understanding, based on diagnosis, mental state and 'mental mechanisms', might be less scientifically reliable than biological information, either of association or of likely mechanism. However, faced with a choice between biology-based evidence (that is more scientifically reliable but less informative about the individual) and psychology-based evidence (that is more informative but less scientificaly reliable), a court is likely to choose the latter. In doing so, the court will feel more at home, as, on a daily basis, courts are used to constructing their own 'understanding' of defendants, albeit without clinical assistance. In that sense, the mismatch between law and psychology is of a different and lesser order from that between law and biology.

Shifting our focus to consideration of issues of criminal responsibility, we can explore some of the foregoing themes in relation to specific mental condition defences, for which strict legal artifices operate and law is highly non-reflexive. BOX 2 describes a number of discrete legal defences, more than one of which can apply in an individual criminal case, that present various mismatches of substance between UK law and neuroscience. These go beyond mere miscommunication and misunderstanding. And similar mismatches apply in other common law jurisdictions (including the United States), which adopt defences that may vary somewhat from UK law in their detail but little in their essence. In summary, defences that abolish, rather than reduce, criminal responsibility offer no clear basis for taking account of contributions to offending from genetic makeup, or from brain function shown by imaging. Only evidence based on strict 'scientific determinism' could be consistent with such defences. By contrast, 'diminished responsibility', by virtue of its loose definition and acceptance that mental abnormality is capable of substantially impairing mental responsibility despite other factors also determining the offence, including, for example, alcohol[35], seems less incongruous with neuroscience.

Preventive detention

Evidence that infers reduced or absent legal culpability can also often be applied to infer that the defendant is at risk of further offending. This is particularly true of personality disorder. Therefore, the factors, biological or other, that can properly be seen as reducing responsibility for criminal actions are also likely to suggest the risk of repetition.

Preventive detention is a topic that deserves a paper in its own right. However, to summarize, the legal sentencing rules relating to the use of expert evidence in risk-based sentencing and 'preventive detention' (see above) are loose and amount, essentially, to the presence of some form of 'mental instability', which effects, and affects, the risk of violence. The opportunities for use, and misuse, of neuroscience towards public protection are therefore frequent, and much less regulated by rules of evidence and procedure than they would be in relation to criminal trials and verdicts *per* se. The need for scientific caution is therefore even greater,

if only because, paradoxically, the 'problem' here in the interaction of law and science is not only of the law 'misunderstanding' or 'distorting' scientific evidence, but of being 'too believing' of it.

There are also provisions in the mental health legislation of England and Wales, rather than in criminal sentencing, for the preventive detention of mentally disordered individuals who pose a risk to others but who are not currently convicted of any offence. The 1983 Mental Health Act allows for detention of mentally ill individuals who are deemed a risk to others, or to their own health or safety, without any evidence of 'treatability'. In addition, although detention of those with 'psychopathic disorder' requires evidence of such treatability, the concept has been so broadly interpreted by the courts[36] and implemented so loosely by Mental Health Review Tribunals[37] as to place little limitation on use of the Act for the purpose of public protection. Furthermore, in the currently debated Draft Mental Health Bill[38], the government is committed to abolition of the treatability test, despite the strong view of a joint parliamentary scrutiny committee that therapeutic benefit should be a pre-requisite of detention for mental disorder[39]. As it is unlikely that this contravenes Article 5 of the European Convention on Human Rights[40], which was incorporated into English Law through the Human Rights Act 1998 (REF. 41), this further emphasizes the risk of (mis)use of biological evidence that shows a tendency towards violence being adopted towards preventive detention. This includes its use towards not only defining the 'diagnostic' basis for detention — mental disorder — but also demonstrating the risk of offending.

In this legal context, the law is loosely defined, and therefore less autopoietic, and this at least reduces the potential for mismatching of law and science. However, civil rights can thereby be seen to lose whether the law is tight or loose. Whereas the former can distort science, the latter allows somewhat untrammelled use of science towards the public policy purposes that lie behind the law.

Conclusions and future perspectives

Law taking on — or, rather, in — science is addressed most straightforwardly by the question 'what is the current state of scientific knowledge in the relevant field, its reliability and validity, and what can it contribute to relevant legal questions?' However, summarizing the potential contribution of neuroscience to law in this way misses the heart of the matter. What is really at issue is whether the model of a given science that is being offered to the courts matches well, or not, the model that is implied by the legal questions to which the science is to be applied. We have argued that there is a profound mismatch of legal and scientific constructs, as well as methods, arising from their expression of different social purposes. More specifically, in terms of the stage that brain science is currently at, the law is unlikely, at least if it fully understands the science it is being offered, to prefer population based evidence of association of violence with biological variables, be they genetic or neuroimaging in nature, to psychological evidence that can suggest, even if not prove, mental mechanisms underlying commission of a particular offence. Rather, whether it is considering the person's level of responsibility for commission of the *actus reus*, or the risk of the individual repeating such offending, courts and Parole Boards are likely to opt for models that offer understanding, as that is what the courts, and law itself, attempt to achieve. The fact that a scientific model is more reliable or more valid will not place it above its competitor(s) if it offers much less legally helpful information to the court or Parole Board.

Only if science were to achieve a very high level explanation of offending in terms of genetics or brain function might the position be altered. Perhaps fortunately, it seems likely that such explanation is a long way off. Indeed, some might say that, were we to achieve such a level of biological understanding of ourselves, we would have 'biologically explained away personhood', and have subsumed both legal and moral responsibility into biology.

Nigel Eastman is at St George's, University of London, Cranmer Terrace, London SW17 ORE, UK.

Colin Campbell is at the Institute of Psychiatry, King's College London, De Crespigny Park, London SE5 8AF, UK.

Correspondence to N.E.
e-mail: neastman@sgul.ac.uk

doi:1038/nrn1887

1. Masters, B. *Killing for Company* (Cape, London, 1985).
2. Wootton, B. (assisted by Seal, V. G. & Chambers, R.) *Social Science and Social Pathology* (Allen and Unwin, London, 1959).
3. Teubner, G. *Law as an Autopoietic System* (Blackwell, Oxford, 1993).
4. *R v. Turner* [1975] 1 QB 834.
5. Eastman, N. L. G. Public health psychiatry or crime prevention? *BMJ* **318**, 549–551 (1999).
6. Horn, D. G. *The Criminal Body: Lombroso and the Anatomy of Deviance* (Routledge, New York, 2003).
7. Beckwith, J. & Alper, J. S. in *Molecular Genetics and the Human Personality* (eds Benjamin, J., Ebstein, R. P. & Belmaker, R. H.) 315–331 (American Psychiatric Publishing, Inc., Washington, DC, 2002).
8. Rubinow, D. R. & Schmidt, P. J. Androgens, brain, and behaviour. *Am. J. Psychiatry* **153**, 974–984 (1996).
9. Ellis, L. A theory explaining biological correlates of criminality. *Eur. J. Criminol.* **2**, 287–315 (2005).
10. Scarpa, A. & Raine, A. Psychophysiology of anger and violent behaviour. *Psychiatr. Clin. North Am.* **20**, 375–394 (1997).
11. Blair, R. J. R. Neurocognitive models of aggression, the antisocial personality disorders, and psychopathy. *J. Neurol. Neurosurg. Psychiatry* **71**, 727–731 (2001).
12. Mobley v. State, 426 S.E.2d 150 (ga. 1993).
13. Mobley v. State, 250 Ga. 292, 455 S.E.2d 61 (1995).
14. Mobley v. Georgia, 516 U.S. 942, 116 S.Ct. 377, 133 L.Ed.2d 301 (1995).
15. Mobely v. Georgia, 269 Ga. 635, 502 S.E.2d 458 (1998).
16. Raine, A. *et al.* Corpus callosum abnormalities in psychopathic antisocial individuals. *Arch. Gen. Psychiatry* **60**, 1134–1142 (2003).
17. Raine, A., Lencz, T., Bihrle, S., Lacasse, L. & Colletti, P. Reduced prefrontal grey matter volume and reduced autonomic activity in antisocial personality disorder. *Arch. Gen. Psychiatry* **57**, 119–127 (2000).
18. Laakso, M. P. *et al.* Psychopathy and the posterior hippocampus. *Behav. Brain Res.* **118**, 187–193 (2001).
19. Volkow, N. D. *et al.* Brain glucose metabolism in violent psychiatric patients. *Psychiatry Res.* **61**, 243–253 (1995).
20. Goyer, P. F. *et al.* Positron-emission tomography and personality disorders. *Neuropsychopharmacology* **10**, 21–28 (1994).
21. Raine, A., Buchsbaum, M. & Lacasse, L. Brain abnormalities in murderers indicated by positron emission tomography. *Biol. Psychiatry* **42**, 495–508 (1997).
22. Kuruoglu, A. C. *et al.* Single photon emission computerised tomography in chronic alcoholism. Antisocial personality disorder may be associated with decreased frontal perfusion. *Br. J. Psychiatry* **169**; 348–354 (1996).
23. Soderstrom, H. *et al.* Reduced frontotemporal perfusion in psychopathic personality. *Psychiatry Res.* **114**, 81–94 (2002).
24. Smith, A. *An fMRI investigation of frontal lobe functioning in psycopathy and schizophrenia during a go/no go task.* Thesis, Univ. British Columbia, Canada (2000).
25. Müller, J. L. *et al.* Abnormalities in emotional processing within cortical and subcortical regions in criminal psychopaths: evidence from a functional magnetic resonance imaging study using pictures with emotional content. *Biol. Psychiatry* **54**, 152–162 (2003).
26. Kiehl, K. A. *et al.* Temporal lobe abnormalities in semantic processing by criminal psychopaths as revealed by functional magnetic resonance imaging. *Psychiatry Res.* **130**, 27–42 (2004).
27. Pridmore, S., Chambers, A. & McArthur, M. Neuroimaging in psychopathy. *Aust. N. Z. J. Psychiatry* **39**, 856–865 (2005).
28. Hare, R. D. *The Hare Psychopathy Checklist — Revised* 2nd edn (Multi-Health Systems, Toronto, 2003).
29. Canli, T. & Amin, Z. Neuroimaging of emotion and personality: scientific evidence and ethical considerations. *Brain Cogn.* **50**, 414–431 (2002).
30. Stark, C. E. & Squire, L. R. When zero is not zero: the problem of ambiguous baseline conditions in fMRI. *Proc. Natl Acad. Sci. USA* **98**, 12760–12766 (2001).
31. Bostock, J. & Adshead, G. in *Encyclopaedia of the Human Genome* (ed. Cooper, D.) (Nature, London, 2003).
32. Rose, N. in *Embracing Risk* (eds Baker, T. & Simon, J.) 209–237 (Univ. Chicago Press, 2001).
33. Yang, Y. *et al.* Prefrontal white matter in pathological liars. *Br. J. Psychiatry* **187**, 320–325 (2005).
34. Woolf, L. C. J. Opening address, Annual Conference, Forensic Faculty, Royal College of Psychiatrists, Brighton, February 2002.
35. *R v. Dietschmann* HL [2003] UKHL 10, *on appeal from: [2001] EWCA Crim 2052*
36. *Reid v. The Secretary of State for Scotland* [1998] 1 All ER 481.
37. Peay, J. *Tribunals on Trial* (Clarendon, Oxford, 1989).
38. Draft Mental Health Bill 2004.
39. Report of the Joint Parliamentary Scrutiny Committee for the Draft Mental Health Bill, HL Paper 79-II, HC 95-II, London, The Stationary Office (2005).
40. *Winterwerp v. The Netherlands* [1979] 2 EHRR 387.

41. Human Rights Act 1998.
42. Brunner, H. G., Nelen, M., Breakefield, X. O., Ropers, H. H. and van Oost, B. A. Abnormal behaviour associated with a point mutation in the structural gene for monoamine oxidase A. *Science* **262**, 578–580 (1993).
43. Rhee, S. & Waldman, I. D. Genetic and environmental influences on antisocial behaviour: a meta-analysis of twin and adoption studies. *Psychol. Bull.* **128**, 490–529 (2002).
44. Caspi, A. *et al.* Role of genotype in the cycle of violence in maltreated children. *Science* **297**, 851–854 (2002).
45. Foley, D. L. *et al.* Childhood adversity, monoamine oxidase A genotype, and risk for conduct disorder. *Arch. Gen. Psychiatry* **61**, 738–744 (2004).
46. Sluyter, F. *et al.* Towards an animal model for antisocial behaviour: parallels between mice and humans. *Behav. Genet.* **33**, 563–574 (2003).
47. Nelson, R. J. & Chiavegatto, S. Molecular basis of aggression. *Trends Neurosci.* **24**, 713–719 (2001).
48. Nelson, R. J. *et al.* Behavioural abnormalities in male mice lacking neuronal nitric oxide synthase. *Nature* **378**, 383–386 (1995).
49. Chiavegatto, S. Brain serotonin dysfunction accounts for aggression in male mice lacking neuronal nitric oxide synthase. *Proc. Natl Acad. Sci. USA* **98**, 1277–1281 (2001).
50. *Bratty v. A-G For Northern Ireland* [1963] AC 386; [1961] 3 All ER 523–39 956, 57).
51. *R v. McNaughton* (1843) 10 Cl and Fin 200.
52. Section 2 Homicide Act 1957.
53. *R v. Lloyd* [1966] 2WLR 13.
54. *DPP v. Camplin* [1978] 2 All ER 168.
55. *R v. Morhall* [1993] 4 All ER 888.
56. Attorney General for Jersey v. Holley (Jersey) [2005] UKPC 23 (15 June 2005).
57. *R v. Duffy* [1949] 1 All ER 932 (2005).
58. *Luc Thiet Thuan v. R* [1997] AC 131 (PC).

Competing interests statement
The authors declare no competing financial interests.

OPINION

Mobilizing the base of neuroscience data: the case of neuronal morphologies

Giorgio A. Ascoli

Abstract | Despite the explosive growth of bioinformatics, data sharing has not yet become routine in neuroscience, possibly because of several broad-spanning issues, from data heterogeneity to privacy regulations. We present the case of neuronal morphology as an ideal example of shareable data. Drawing from recent experience, we argue that the tremendous research potential of existing (and largely unused) digital reconstructions should diffuse any reticence to sharing this type of data.

Data sharing is a hot topic in biomedical research. The explosive accumulation of knowledge in the natural and health sciences during recent years has created exciting opportunities for scientific integration that were not even imaginable a few decades ago. In particular, the massive amount of available information in digital format (for example, gene sequences and protein structures) enables a powerful form of 'secondary discovery' based on data mining, re-analysis and modelling.

The advantage and necessity of openly sharing data collected in one's laboratory are recognized in the thriving field of bioinformatics. There, combined and converging pressure from funding agencies, academic journals and peers has established a culture of routine data sharing, at least for several common data types. A researcher unwilling to deposit their primary data in a public repository would be unable to publish the related results in most top journals. The impact of that research would be further dampened by the lack of citations deriving from secondary discovery. In molecular biology, the visibility of shared data is associated with a laboratory's success and prestige.

In neuroscience, the story is quite different. Bluntly stated, data sharing is still an uncommon practice. Funding agencies have put forward considerable effort to foster and encourage neuroscience data sharing, starting with the pioneering vision of the Human Brain Project[1,2], which was launched in 1993 to develop and support the new science of neuroinformatics. This trend is continuing through the most recent programs under the Blueprint initiative[3], a framework to enhance cooperative activities among National Institutes of Health units that support research on the nervous system. The benefits and necessity of data sharing for scientific discovery are broadly recognized[4,5], and the neuroinformatics community is considerably active[6], with a dedicated journal[7], a Society for Neuroscience committee, international coordinating facility, conferences and web portals[8]. Several individual laboratories are single-handedly sharing a large amount of data[9,10], and some journals mandate data deposition in public repositories on publication.

However, several issues have so far prevented the neuroinformatics movement from establishing a broader and more pervasive culture of data sharing akin to that in the field of molecular biology[11,12]. The heterogeneity of neuroscience data constitutes an undeniable challenge. A vast amount of bioinformatics research is concentrated on sequences (genomes and proteins) and three-dimensional structures (crystallography or nuclear magnetic resonance). By contrast, neuroscience research is more sparse and distributed, spanning scales (from molecules to cells to whole brains), techniques (for example, from histology to electrophysiology to microscopy at the cellular level alone), and, consequently, data types.

Almost every subfield of neuroscience with a well-defined data type has its own peculiar problems in relation to data sharing. For non-invasive imaging of human subjects, privacy and HIPAA (Health Insurance Portability and Accountability Act) regulations constitute a serious concern, as the personal identity of the subjects can, in principle, be derived from high-resolution brain images[13]. For microscopy and electrophysiology, the cost and time involved in sharing data meaningfully (that is, after extensive annotation, format conversion and so on) exacts a considerable toll on the primary research effort[14]. For synaptic physiology and transduction pathways, open data distribution is impeded by the prospect of commercial interest from the pharmaceutical industry[6]. For gene expression patterns, the need for a meaningful control of quality, reproducibility and validation of microarray profiling poses a major challenge[15–17].

Attempts have also been made to collect, organize and inventory neuroscience knowledge from the primary literature. Examples include comprehensive projects encompassing all of brain research[18], and more delimited efforts focusing on specific domains, such as cortical columns[19], connectivity[20] or cellular properties[21]. It would be ungenerous to criticize these still developing knowledge