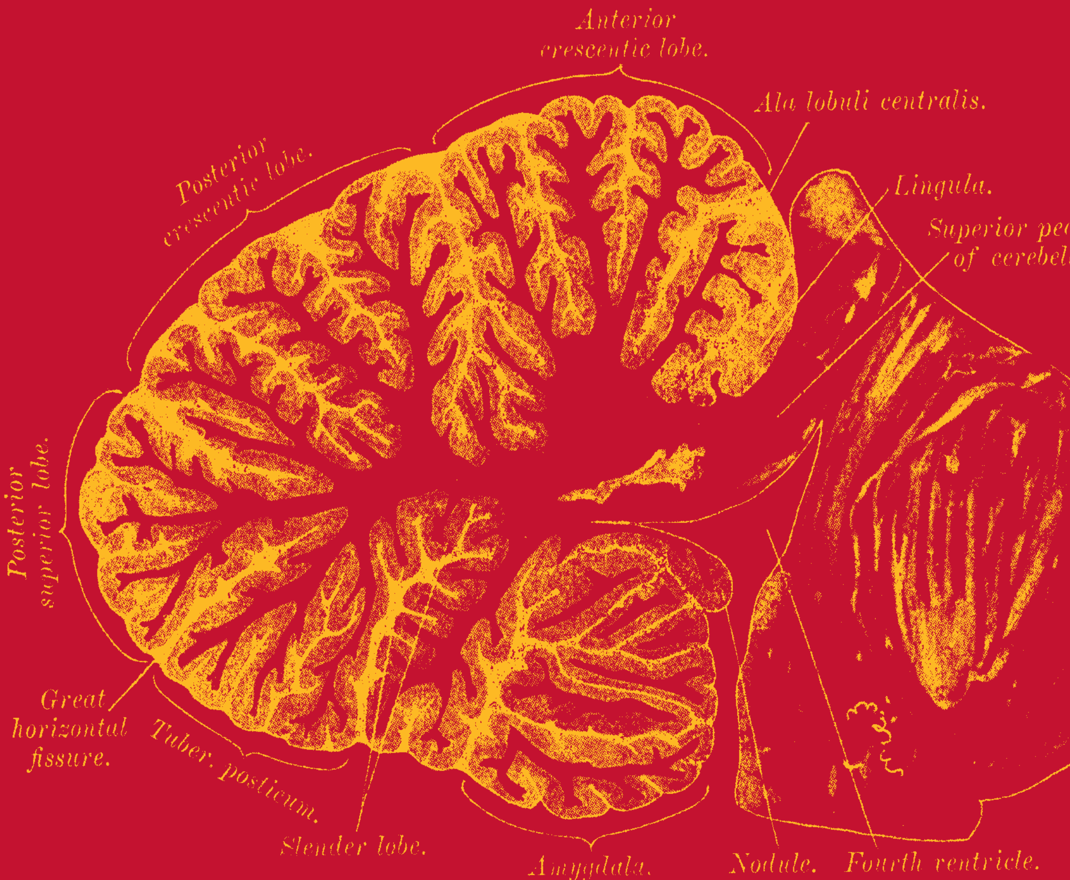

Brain Waves Module 4:

Neuroscience and the law

December 2011

EXCELLENCE IN SCIENCE

THE ROYAL SOCIETY

RS Policy document 05/11
Issued: December 2011 DES2420

ISBN: 978-0-85403-932-6

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Cover image: This diagram of the cerebellum (a structure at the bottom of the brain) shows the amygdala, which plays an important role in reward and emotion processing. The early development of the amygdala relative to other brain areas is thought to account for the heightened emotional responses and risky behaviour characteristic of adolescence. Image from *Anatomy, descriptive and surgical*, Henry Gray, edited by T.Pickering Pick and Robert Howden,1977, New York.

Brain Waves Module 4: Neuroscience and the law

Contents

Summary

The human brain is not viewed in the same way as other organs. The brain holds the key to mind and behaviour, and so to most it has a 'special' status. The relatively young field of neuroscience is the study of the brain and nervous system. Neuroscientists seek to determine how brain function affects behaviour. The law is concerned with regulating behaviour, and so it is reasonable to ask whether and if so how, neuroscience could, or should, inform the law. The Royal Society, the UK's national academy of science, has sought here to set out where neuroscience might offer insights to the law, and current limits to its application.

Many questions have been asked about what neuroscience might offer for the law. For instance, might neuroscience fundamentally change concepts of legal responsibility? Or could aspects of a convicted person's brain help to determine whether they are at an increased risk of reoffending? Will it ever be possible to use brain scans to 'read minds', for instance with the aim of determining whether they are telling the truth, or whether their memories are false? It has been suggested that '*for the law, neuroscience changes nothing and everything*'[1]. This report takes a different position: that discoveries in neuroscience (or in genetics or psychology) will not completely revolutionise the theory and practice of the law in the near future; but there are already some important practical implications of recent neuroscientific discoveries, which should impact on the law, and there will certainly be many more over the next few years.

For example, findings from neuroscience may raise questions over the age of criminal responsibility. Although the potential is at present unclear, it is possible that neuroscientific information could be used as part of risk assessments. It is also possible that imaging studies may in the not too distant future provide evidence of the nature of pain. This would be relevant to many civil cases, concerned with whether a claimant's suffering and pain are real or exaggerated. In addition, neuroscience may also be used further to strengthen the diagnosis of 'Shaken Baby Syndrome' or 'Non Accidental Head Injury' (NAHI).

While there are examples, such as those above, of where neuroscience may provide useful insights, it is worth sounding a note of caution: claims that murderers can be identified by imaging studies of their brains, or that there is a gene for psychopathy or for violent or antisocial behaviour are completely wide of the mark.

If neuroscience is to feed usefully into the law, there are a number of challenges to its use that must first be overcome. Some of these might apply to the intersection of science and law more broadly; however this report has focused on neuroscience. The report makes a number of recommendations for bridging the gap between legal professionals and

1 Greene and Cohen 2004 *For the law, neuroscience changes nothing and everything*. Philosophical Transactions of the Royal Society B 359, 1775–1785.

neuroscientists to better communicate relevant findings; for training and education; and for building applied research capacity:

Recommendation 1: An international meeting should take place every three years to bring together those working across the legal system with experts in neuroscience and related disciplines. The aim of this meeting should be to discuss the latest advances in areas at the intersection of neuroscience and the law to identify practical applications that need to be addressed.

Recommendation 2: The systems used by legal professionals to identify, access and assess the quality of expertise in specific scientific areas should be reviewed by the judiciary and the Bar Council to ensure the latest advice is made available. This should be carried out in consultation with learned societies such as the British Neuroscience Association, and other specialist societies as appropriate.

Recommendation 3: University law degrees should incorporate an introduction to the basic principles of how science is conducted and to key areas of science such as neuroscience and behavioural genetics, to strengthen lawyers' capacity to assess the quality of new evidence. Conversely, undergraduate courses in neuroscience should include the societal applications of the science.

Recommendation 4: Relevant training should be made available where necessary for judges, lawyers and probation officers. This should count towards Continual Professional Development (CPD) requirements for lawyers, and for judges might be administered through the Judicial College's programme of seminars.

Recommendation 5: Further research is needed on areas including:

- The National Institute for Health Research (NIHR) should encourage neuropathology studies to characterise Non-Accidental Head Injury (NAHI) and distinguish it from accidental or natural causes.
- The Economic and Social Research Council (ESRC) should encourage studies into the relative efficacy of different models of risk assessment in the context of probation, and a possible role for neuroscience to be used in combination with existing approaches.

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The members of the Working Group involved in producing this report were as follows:

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This report has been reviewed by an independent panel of experts and also approved by the Council of the Royal Society. The Royal Society gratefully acknowledges the contribution of the reviewers. The review panel were not asked to endorse the conclusions or recommendations of the report, nor did they see the final draft of the report before its release.

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Acknowledgements

We would like to thank all those consulted during the course of this study, including the neuroscientists, policy makers, barristers and judges who provided feedback at various stages, and those who attended the workshop, *The brain and the law*, held in partnership with the Arts and Humanities Research Council (AHRC) on 2nd June 2011. We are also grateful to the Sackler family for their generous funding of the 2nd Royal Society-National Academy of Sciences Sackler Forum on the subject of neuroscience and the law, held on 2nd – 3rd March 2011.

1 Introduction

Understanding how the brain works gives us an insight into the mental processes that underpin human behaviour. As the law is primarily concerned with regulating people's behaviour, it follows that knowledge about how the brain works may one day be of some relevance to the law.[2]

Neuroscience is the empirical study of the brain and connected nervous system, and contemporary neuroscience seeks to explain how human behaviour arises from brain activity. This is not an easy task. The human brain contains around one hundred billion (10^{11}) nerve cells or neurons and one hundred trillion (10^{14}) synapses or connections between nerve cells. But, over the past thirty years, neuroscientists have made remarkable progress. Neuroscience has shed light on how the brain and certain mental processes can work, and research is showing just how complex the links between brain activity, mental processes and behaviour really are.

For example, neuroscience has shown correlations between patterns of activity in the human brain, mental functions (such as thinking, feeling, sensing, attention, memory and consciousness) and particular types of behaviour. Research has shown that both genes and the environment can affect mental functions, patterns of brain activity and behaviour. It is known that interactions between genes and environment affect changes in the brain[3] and that the brain continues to develop beyond adolescence and into adulthood[4]. But it is also important to recognise that there is no direct mapping of mental function to specific areas of the brain[5], and that there are huge differences between individuals[6].

The application of findings such as these (and many others) to the law may not be as simple as in other disciplines.[7] The remit of this report is to discuss the relevance and utility of these findings from neuroscience to the law. In what follows, a relatively broad view of 'neuroscience' is taken, to include some discussion of behavioural genetics and psychology. At present there may be relatively little neuroscience that can be directly applied

2 In the United States, the MacArthur Foundation has funded a major programme of work on neuroscience and the law, and at least one university now runs a graduate seminar course on 'Neurolaw'. The French government has also been funding a programme on 'Neuroscience and Public Policy' since 2009, and the European Science Foundation funds a European Neuroscience and Society Network.

3 Meyer-Lindenberg and Weinberger 2006 *Intermediate phenotypes and genetic mechanisms of psychiatric disorders. Nature* Reviews Neuroscience **7**, 818–827.

4 Gogtay *et al.* 2004 *Dynamic mapping of human cortical development during childhood through early adulthood*. Proceedings of the National Academy of Sciences **101**, 8174–8179.

5 Poldrack 2011 *Mapping Mental Function to Brain Structure: How Can Cognitive Neuroimaging Succeed*? Perspectives on Psychological Science **5**, 753–761.

6 Mohr and Nagel 2009 *Variability in brain activity as an individual difference measure in neuroscience*. The Journal of Neuroscience **30**, 7755–7757.

7 For example, in the health sector there are many professionals whose job it is to ensure new scientific breakthroughs find their way into policy and society.

to the law, but this will surely change over the next ten to twenty years. This report also takes a broad view of 'the law' (although perhaps with more emphasis on criminal than civil law), and has attempted to consider not only what happens in court trials, but also, for instance, what happens in sentencing and probation. It has not been possible within the scope of this report to discuss every possible interaction of neuroscience and law. Instead, some key areas of debate are highlighted, with examples that refer to the legal system of England and Wales, except where stated otherwise.

1.1 Terms of reference

The terms of reference for this study were to:

- Provide an introduction to the questions raised around the intersection of neuroscience and law, and the link between the brain, mind states and behaviour (see Chapter 1).
- Provide an assessment of the extent to which neurotechnologies might be able, now or in the future, to contribute to the quality of decision-making in legal proceedings (see Chapter 2).
- Discuss the capabilities and limits of neuroscience and neurotechnologies as they relate to the law or the legal process (see Chapter 3).
- Provide an overview of which areas of neuroscience and neurotechnologies might impact on decision-making in the law (see Chapter 4), including:
  - Risk
  - Memory, including reliability of witness testimony
  - Deception
  - Pain
  - Neuropathology
- Discuss how the use of these technologies in legal proceedings might best be governed to allow new insights to be used where appropriate whilst minimising inappropriate use (see Chapter 5)

This is one of four modules in the Royal Society Brain Waves series on neuroscience and society.

2 Key concepts and techniques in neuroscience

This chapter introduces some of the techniques and key working concepts adopted by neuroscience. It aims to draw the reader's attention to the opportunities, but also to the limitations and challenges involved in drawing conclusions from neuroscientific studies, and the prospects for developing future applications. For a much broader discussion refer to Module 1 of the Brain Waves study.

2.1 Linking brain, mind and behaviour

As investigation of the relationship between brain and mind has developed, researchers have been able to describe mental processes that relate nerve cells or neural circuits to the behaviour of individuals. Many of these mental processes such as thinking, feeling, sensing, attention, memory, and consciousness are regularly used in common language. But although mental processes are helpful in explaining the relationship between brain and mind, the mappings from brain activity to mental process and from mental process to bahaviour, remain complex and poorly understood.

Moreover most experiments that investigate the relationship between brain activity and behaviour necessarily use simplified laboratory situations. Generalising findings from these experiments to complex 'real world' situations is difficult and uncertain. An appreciation of the limits of neuroscientific techniques can inform the assessment of how useful these findings can be, and importantly, highlight areas for productive research.

2.2 Individual differences and the role of genes and the environment

The brain is constantly changing. There is variation been individuals in the structure and function of the brain and the mental processes that underpin behaviour. Indeed, everyday experience shows that individuals respond very differently to specific situations. Why is that? Evidence suggests that both genes and the environment, and hence people's unique, individual, lifelong experiences, play a role in modulating behaviour[8].

However genetic influences on the brain are not yet well understood. Genetic predispositions may have an effect on behaviour, but examples where a simple genetic defect alone can act to affect behaviour are rare. An example from the field of health would be the gene mutation for Huntington's disease[9]. In the majority

8 Rutter 2006 *Genes and behaviour. Nature-nurture inter-play explained*. Oxford: Blackwell.

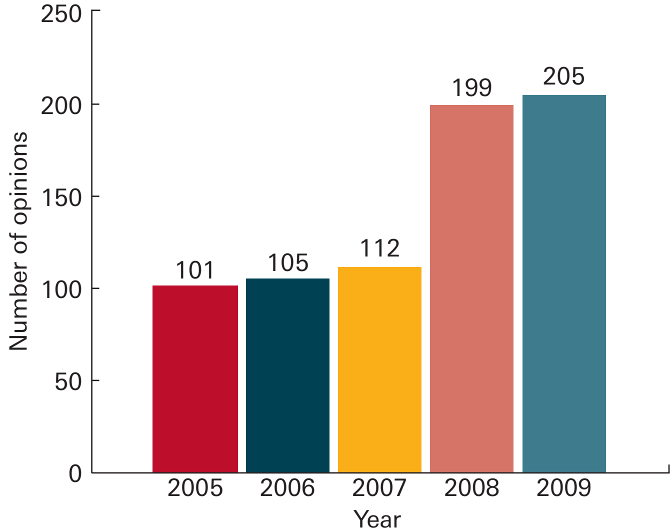
9 Huntington's disease is a neurological disorder resulting in the degeneration of cells in the brain. The symptoms of impaired memory, personality change and progressive cognitive decline are the result of a genetic mutation which causes the sufferer to produce an abnormal version of the protein Huntingtin.

of cases, multiple genes affect behaviour, and their individual effects would be very small[10]. In addition, the physical and behavioural attributes linked to specific genes are affected by a range of environmental factors, including diet, exposure to toxins and social interactions[11].

2.3 Techniques used in neuroscience

The use of evidence from neuroscience in the courts is increasing (as shown in Figure 1). This chapter focuses on neuroimaging as an example of how neuroscience and neurotechnologies have been used to infer information about an individual's mental state. However, there are many other neuroscientific techniques that could also be relevant or useful, some of which are described in more detail in Brain Waves Module 1 (Section 2.1).

Figure 1. Distribution by Year of Defendant-Based Behavioural Science Opinions 2004–2009. This chart shows the number of cases by year, from a sample of 722 from 2005–2009 in the USA, in which neurological or behavioral genetics evidence is introduced in criminal cases on behalf of a criminal defendant. Source: Professor Nita Farahany database, 2011. Personal communication.



10 Bishop 2009 *Genes, cognition and communication: insights from neurodevelopmental disorders*. Annals of the New York Academy of Science **1156**, 1–18.

11 Rutter *et al.* 1999 *Integrating nature and nurture: Implications of person-environment correlations and interactions for developmental psychopathology*. Development and Psychopathology **92**, 335–364; Van Praag *et al.* 2000 *Neural consequences of environmental enrichment*. Nature Reviews Neuroscience **1**, 191–198; Champagne and Curley 2005 *How social experiences influence the brain*. Current Opinion in Neurobiology **15**, 704–709.

The most common technique for measuring human brain structure and activity is magnetic resonance imaging (MRI). While structural MRI produces pictures of brain anatomy, more recently functional MRI (fMRI) has been developed that can produce dynamic images that reflect patterns of brain activity. Both structural and functional MRI have very good spatial resolution[12]. But the ability of functional MRI to resolve the timing of brain activity is hampered by its reliance on the sluggish responses of blood vessels to changes in blood oxygenation.

In contrast to the good spatial and poor temporal resolution of fMRI, electroencephalography (EEG) and magnetoencephalography (MEG) measure the tiny electrical or magnetic fields produced on the surface of the scalp by brain activity. As they measure electrical activity directly, they have much higher temporal resolution but relatively poor spatial resolution. As a consequence, neuroscientists sometimes use EEG/MEG in combination with MRI to secure converging evidence with complementary strengths in spatial and temporal information.

These techniques therefore offer good, but still indirect measures for what is actually happening in the brain. Findings from neuroscience will often need to be complemented with other techniques and approaches (such as behavioural observations) to reach rounded conclusions.

2.4 Some cautionary words on interpreting neuroscientific data

The application of neuroscientific data to the law is not a straightforward matter, and this section discusses some of the important considerations that must be borne in mind. Any experimental finding needs to be independently replicated, and be the result of adequate experimental design. But there are additional more specific problems: for example, any neuroscientific assessment of criminals may be invalid as the inevitable time lag between the crime and the assessment may make it impossible to infer the state of the brain at the time the crime was committed. Moreover, the compliance that is required from participants during MRI scanning may also limit the application of these technologies. Further discussion of these points can be found in the USA Reference Manual of Scientific evidence[13].

2.4.1 Demonstrating causality

Techniques such as neuroimaging, which permit neuroscientists to measure changes

12 Spatial resolution refers the level of detail of an acquired image; in particular how well points close together can be distinguished from one another. MRI has spatial resolution in the order of a few millimetres, allowing intricate structures to be visible and pinpointed, this resolution is superior in comparison to contemporary neuroimaging technologies of EEG and MEG (refer to Brain Waves Module One).

13 Refer to Greely and Wagner 2011 *Reference Guide to Neuroscience* in the *Reference manual on scientific evidence*. The National Academies Press: Washington DC.

in brain activity, may allow an experimenter to detect a correlation between some particular type of behaviour and brain activity. But such a correlation, whether it is between brain structure or brain activity and behaviour, does not amount to reliable evidence of causation. For example, an observed correlation between differences in brain structure and political conservatism or liberalism[14] does not mean that differences in brain structure *cause* particular political beliefs. Alternative explanations might be that political beliefs affect brain structure, or that both political beliefs and brain structure were both independent consequences of some other cause.

Other additional experiments are needed to establish the direction of causality.[15] An experiment that established that a change in brain structure (caused for example by an injury or stroke) resulted in a change in behaviour, would imply that the one influenced the other (see Box 2 for an example of this).

It is important to recognise that ideas about causality in neuroscience are not necessarily the same as those that operate in the legal sphere. In law, where it is claimed that event x caused outcome y, then it must at least be shown that x satisfies the so-called 'but-for' test. If y would not have occurred but-for x, then x is at least a significant part of the causal story leading to y. However, this does not establish that x is a sufficient cause of y or that x should be singled out as '*the* cause of y' where y is the outcome of concurrent or cumulative conditions. Additional investigations would be necessary to establish the significance of x. Box 2 illustrates this point too.

2.4.2 The reverse inference problem

One of the most important discoveries about the human brain has been that there is a systematic relationship between particular brain areas and particular functions. For example, the brain areas associated with vision are located in the occipital lobe at the back of the brain. However, it is now clear that such consistent relationships between a brain structure and a mental process are not straightforward 'one-to-one' links. Instead, a particular brain structure may be involved in many (but not all) mental processes; and a particular mental process will often involve several (but not all) brain areas. This 'many-to-many' mapping of mental processes onto brain areas or structures makes it difficult if not impossible to infer particular mental processes from the observation of activity in a particular area. The presence of brain activity in a particular area may result from several different mental processes for example those of pain perception, arousal and affect. The 'fallacy of reverse inference[16]'

14 Kanai *et al.* 2011 *Political orientations are correlated with brain structure in young adults*. Current Biology **21**, 677–680.

15 For example see the use of natural experiments such as twin studies discussed in Rutter 2007 *Proceeding from observed correlation to causal inference: the use of natural experiments*. Perspectives on Psychological Science . **2**, 377–395.

16 Poldrack 2006 *Can cognitive processes be inferred from neuroimaging data*? Trends in Cognitive Sciences **10**, 59–63.

refers to the misguided and incorrect attempt to conclude from observation of activity in an area that a particular mental process was taking place. This is rarely possible.

2.4.3 Applying generalisations from group studies to individuals

Due to the inherent different between individuals (refer to Chapter 2.2), neuroscientific research is often based on data collected on groups of individuals. This permits an 'average' representation, which can then form a basis for investigation of differences between each experimental group. The law however is concerned with conclusions about a particular individual. This presents an inherent problem for the application of knowledge based on group studies to the law.

For example, a statistically significant difference between two groups does not prove that every individual in each of the two groups can be distinguished. In much behavioural research, within-group differences are often greater than the average difference between two groups. So an individual who belongs to one group may well resemble behaviourally many individuals who belong to the other. This is illustrated using a simple example in Figure 2.

Furthermore, much academic research with human participants, including neuroscientific research, employs convenience samples – in practice often university students. Students may not always be law abiding, but they are hardly a representative sample of the people who appear in court, so there may be a danger in generalising from an academic study to cases of interest to the law[17].

2.4.4 Interpreting statistical evidence

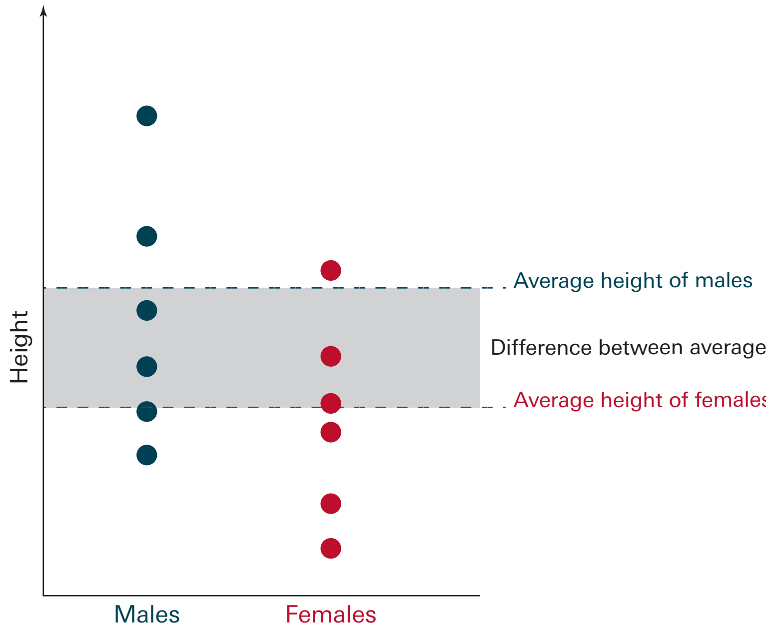
Much neuroscience evidence is statistical in nature – providing evidence about the probabilities of certain traits in populations rather than facts about individuals. Below are some key questions about such evidence that must be addressed. This is based on the Royal Statistical Society Practitioners guide No.1.[18]

- What is the question that the evidence purports to be addressing?
- On what sample were the probabilities obtained? Is it relevant to the court case being considered? Was the size of the sample adequate for the purpose?
- Does the probability claimed confuse the conditionals (the 'prosecutor's fallacy')? In other words, does the probability deal with the question: 'Assuming that the accused is innocent, what would be the probability of finding this trace evidence on him?' Or the quite different question: 'Assuming that this trace evidence has been found on the accused, what is the probability that he

17 The use of unrepresentative subject groups in studies is discussed in: Henrich *et al.* 2010 *Most people are not WEIRD*. Nature **466**, 29.

18 Aitken *et al.* 2010 *Communicating and interpreting statistical evidence in the administration of criminal justice.* Royal Statistical Society. Available online at: www.rss.org.uk/site/cms/contentviewarticle.asp?article=1132

Figure 2. This diagram (not based on real data) shows the heights of two groups of male and female individuals. It can be seen that whilst there is a difference between the means of the male and female groups, the difference between the two means is smaller than the difference between the tallest and shortest male, and tallest and shortest female. Some of the males are very similar in height to some of the females.



is innocent?' These sound very similar but they are quite different and lead to different conclusions.

- Does the statistical probability for the co-occurrence of two events (eg two cot deaths, or two brain tumours) assume that the risks for each are truly independent (ie there could not be some other common cause)? Independence must always be demonstrated and not assumed.
- Is that probability compared with some alternative possibility? (Experts should always address at least one pair of competing propositions).
- Does the expert's report misleadingly stray into areas of guilt or innocence that should be left to the Court?

2.4.5 Countermeasures

Countermeasures refer to ways in which MRI assessments could be disrupted to make results unusable or misleading. One strategy is intentional movement. MRI scanning is very sensitive to changes in position, as much as a few centimetres will cause a scan to be useless. Intentional movement will be visible to the assessor and explicit non cooperation is likely to result in negative inferences about a defendant. In this respect, hidden strategies whereby a defendant could change what they are thinking to conceal their true mindsets may be more useful, especially if trying to beat MRI based lie detection. This may also be useful to mislead assessments of pain: neuroimaging studies have shown that similar regions are activated when performing and imagining the same task[19] (although the activation produced from imagining is smaller than from actually performing the task). Thus a participant could vividly imagine a time when they were previously in pain to try and mimic the similar brain responses.

19 Roth *et al.* 1996 *Possible involvement in primary motor cortex in mentally stimulated movement: a functional magnetic resonance imaging study*. NeuroReport **7**, 1280–1284.

3 Generic challenges in applying neuroscience to the law

The previous chapter presented some key concepts in neuroscience and discussed the limitations of interpreting neuroscientific data. This chapter considers some of the wider challenges presented by applying neuroscience to the law.

3.1 The intersection of neuroscience and the law

Neuroscience and law are very different disciplines. The different nature of the work involved, from laboratory to office to courtroom, can lead to cultural differences between the two groups. There are also differences of language, with many terms employed by both scientists and lawyers having different meanings. For instance, Box 3 in this chapter highlights the different meaning of the word 'reliable' in science and in the law[20].

Neuroscience alone cannot answer questions of relevance to the law. It must be used in conjunction with other disciplines such as behavioural genetics, psychology, behavioural sciences and sociology. Neuroscience can reveal some, but crucially not all, of the conditions necessary for behaviour and awareness[21].

20 See Goodstein 2011 *How science works* in the *Reference manual on scientific evidence*. The National Academies Press: Washington DC.

21 For further discussion, see: Tallis 2010 *What neuroscience cannot tell us about ourselves*. The New Atlantis **29**, 3–25.

3.2 Defining Responsibility

The creation and the enforcement of the law[22] is in essence a means of regulating human behaviour. If certain features of the brain were found to result in an increased propensity to behave in certain ways, this might affect how people are seen as being responsible for their actions. As the law is concerned with behaviour, it might therefore be argued that neuroscientific findings could have profound consequences for the law. This section begins with an examination of legal responsibility, and whether evidence from neuroscience will be of relevance.

3.2.1 Neuroscience and legal responsibility

In modern societies, ideas about 'responsibility' are linked to the extent to which people choose to act in a certain way, and their ability to have acted otherwise. In the jurisprudence of punishment and responsibility, distinctions are drawn between acts that are (fully) justified, that are (fully) excused, and that merely merit some mitigation; and then there are questions about which classes of act fall into which of these categories. Inevitably law draws upon approaches in science and philosophy to adapt its own view of what it means to be 'responsible'.

22 The term law is used here to mean the rules by which communities of humans govern themselves.

It has been argued that the discoveries of neuroscience undermine common assumptions about free will and, with that, assumptions about both responsibility and autonomy[23]. However, within the practice of law, the philosophical question of whether or not humans have free will is not relevant. There is a significant body of literature on neuroscience and free will. This is discussed further in Chapter 2.4 of *Brain Waves Module 1: Neuroscience, society and policy*.

In addition, although neuroscience purports to increase understanding of the way in which particular neural events are linked to particular actions, even if neural events are shown to cause certain acts, it does not follow that it is unfair or inappropriate to hold people responsible for their acts. Arguably, there are many antecedents which exercise causal effects on actions. Some of these antecedents are chemical, neurological or biological; others are social, peer example and pressure, education, knowledge and beliefs. However, the law (as a social practice) still needs to determine which particular antecedents or causes justify, excuse, or mitigate a particular action, and which do not. Can neuroscience contribute useful evidence?

For example, in criminal offences of specific intent the prosecution is required to prove that the accused intended the criminal consequences of his act at the time he committed it. Neuroscience might[24] be used to show that this mental state (*mens rea)* is not present, and that criminal and perhaps moral responsibility for the act is therefore diminished. In England and Wales, the plea of 'diminished responsibility' is a partial defence only in murder cases (reducing charges from murder to manslaughter). In a case in Italy, genetic evidence has been successful in reducing the sentence of a convicted murderer, both at trial and again on appeal[25].

Box 1 shows another example of how neuroscientific evidence might be used to inform concepts of responsibility in the case of minors.

3.2.2 Reduced responsibility

In addition to providing evidence that might affect the outcome of trials in which diminished responsibility (in murder cases only) or other mental condition defence is an issue, neuroscience may also be used more widely in the future as an argument for reducing a sentence following conviction.

For some criminal offences, neuroscience may be used to suggest that the degree of responsibility of the defendant for their actions is mitigated in a manner which should be reflected by a reduced sentence. It might also be used to inform decisions

23 Chivers 2010 *Neuroscience, free will and determinism: 'I'm just a machine'.* The Telegraph. Available online at: www.telegraph.co.uk/science/8058541/Neuroscience-free-will-and-determinism-Im-just-a-machine.html

24 See § 2.4 for a short discussion on the limitations of applying neuroscientific findings to the law.

25 Feresin 2009 *Lighter sentence for murderer with 'bad genes'.* Nature News. Available online at: www.nature.com/news/2009/091030/full/news.2009.1050.html. The defendant had one particular allele of the MAOA gene (see § 4.1).

Box 1: A neuroscientific perspective on brain development and criminal responsibility

In England the age of criminal responsibility is ten. This means that up to the age of ten a child will not be held responsible for criminal acts. From the age of ten however, in the eyes of the law, a child is accountable in the same way as an adult for their behaviour, and is deemed sufficiently mature to stand trial and to engage in legal processes (the child is 'fit to plead'). This contrasts with other Western European countries that have higher ages of criminal responsibility[26].

Neuroscience is providing new insights into brain development, revealing that changes in important neural circuits underpinning behaviour continue until at least 20 years of age. The curves for brain development are associated with comparable changes in mental functioning (such as IQ, but also suggestibility, impulsivity, memory or decision-making), and are quite different in different regions of the brain. The prefrontal cortex (which is especially important in relation to judgement, decision-making and impulse control) is the slowest to mature[27]. By contrast, the amygdala, an area of the brain responsible for reward and emotional processing, develops during early adolescence. It is thought that an *imbalance* between the late development of the prefrontal cortex responsible for guiding behaviour, compared to the early developments of the amygdala and associated structures may account for heightened emotional responses and the risky behaviour characteristic of adolescence[28].

There is huge individual variability in the timing and patterning of brain development. This could be taken to imply that decisions about responsibility should be made on an individual basis at this stage of development.

Neuroscience may also help to provide an understanding of how early adversity alters brain development. Adults who have suffered from adverse early experiences are more likely to demonstrate elevated levels of risk taking behaviours, akin to the behavioural characteristic of adolescence. Studies have revealed that these adults also show heightened neural response in subcortical limbic brain regions during reward processing tasks[29].

26 For instance, the age of criminal responsibility is 18 in Belgium, 16 in Spain, 15 in Norway, Sweden, Finland and Denmark, and 14 in Italy and Germany. From BBC News 2010 *Calls to raise age of criminal responsibility rejected.* Available online at: http://news.bbc.co.uk/1/hi/uk/8565619.stm

27 Gogaty *et al.* 2004 *Dynamic mapping of human cortical development during childhood through early adulthood*. Proceedings of the National Academy of Sciences **101**, 8174–8179.

28 This is discussed in Chapter 2.4 of Brain Waves Module 2: Neuroscience: implications for education and lifelong learning. Available online at: http://royalsociety.org/policy/reports/brainwaves2/.

29 Dillon *et al.* 2009 *Childhood adversity is associated with left basal ganglia dysfunction during reward anticipation in adulthood.* Biological Psychiatry **66**, 206–213.

In conclusion, it is clear that at the age of ten the brain is developmentally immature, and continues to undergo important changes linked to regulating one's own behaviour. There is concern among some professionals in this field that the age of criminal responsibility in the UK is unreasonably low[30], and the evidence of individual differences suggests that an arbitrary cut-off age may not be justifiable.

as to whether or not continued detention may be necessary to protect society from the release of a prisoner identified by the system as potentially dangerous (this is discussed further in Chapter 4.1).

Imaging evidence suggests that there are differences between the brains of people diagnosed as 'psychopaths' and others, and there is also evidence of a heritable component to psychopathy (see section 4.1). Does this mean that evidence of psychopathy should reduce a convicted defendant's sentence as they are less responsible for their acts? Or, on the contrary, that a treatment regime or longer incarceration is warranted on public safety grounds? Neuroscientific or genetic evidence alone of this sort may not provide better grounds for a reduced or extended sentence than would evidence of neglect or abuse in childhood, however it may be beneficial if used in conjunction with other methods. Furthermore, neuroscience may prove useful in providing evidence about an individual's response to various forms of intervention or rehabilitation. For instance, there are studies suggesting that certain individuals may not respond well to punitive measures[31]. Better understanding of mental conditions and their treatment might also provide insights into the relationship between mental disorders and crime.

In summary, although neuroscience does not necessarily challenge all traditional notions of responsibility, it does suggest that adolescence, for instance, may be a mitigating circumstance. It has been suggested that neuroscience might also be relevant in assisting in providing an evidence base for appeals to higher courts against conviction or sentence in a few very specific cases involving injury or other damage to the brain. Box 2 below presents an example of one such case in the USA.

3.3 The use of neuroscience in court

It is difficult to ascertain to what extent any particular kind of evidence, such as neuroscientific evidence, is used in the courts. The deliberations of first instance courts (trial courts) in England and Wales are not generally formally recorded in the law reports. Hence, in the absence of

30 Vizard et al 2010 *Children and court* (letter to the Times newspaper), 7 July 2010.

31 Dadds and Salmon 2003 *Punishment insensitivity and parenting: temperament and learning as interacting risks for antisocial behaviour*. Clinical Child and Family Psychology Review. **6**, 69–86.

Box 2: Orbitofrontal tumour and 'acquired paedophilia'[32]

An American man in his late 40s, was found to have developed unusual sexual arousal behaviours and had begun to secretly collect child pornography. He was eventually removed from the family home for making sexual advances towards his step-daughter, and was subsequently diagnosed with paedophilia and convicted of child molestation. The man was ordered by the judge to undergo rehabilitation for sexual addiction or go to jail. Attempts to complete rehabilitation were marred by the man's inability to restrain himself from soliciting sexual favours from staff and other clients and he was expelled from the programme.

The evening before sentencing, the man was admitted to hospital with a headache and balance problems. Neurological examination, which included magnetic resonance imaging (MRI) revealed a cancerous tumour that displaced the right orbitofrontal cortex.

The orbitofrontal cortex is involved in the regulation of social behaviour. Lesions acquired in early life can lead to an impedance in the acquisition of social- and moral-knowledge, which may result in poor judgment, reduced impulse control, and antisocial personality. A similar acquired antisocial personality occurs with adult onset damage, but previously established moral development is preserved. Nevertheless, poor impulse regulation is thought to lead to poor judgement and sociopathic behaviour. Disruption of this system can result in decision-making that emphasises immediate reward rather than long-term gain, impairing the subject's ability to appropriately navigate social situations.

Following examination the tumour was removed and after several days the patient's balance improved and he was able to complete a Sexaholics Anonymous programme. Seven months later the patient was deemed to no longer be a threat to his step-daughter and returned home.

Almost a year later, the man reported persistent headaches and that he had begun secretly collecting child pornography again. Tumour recurrence was revealed by MRI studies and surgery was performed to remove it for a second time. Once again the patient's behaviour returned to normal after a couple of days.

empirical studies of the work of these courts, any estimation of the extent of the *current* use of neuroscientific evidence has to be based on the reports of appeal cases. Because these are likely to be cases in which novel legal issues arise, they may not necessarily accurately reflect practice in courts of first instance.

32 This case is discussed further in Choi 2002 *Brain tumour causes uncontrollable paedophilia*. New Scientist, 21 October 2002. Available online at: www.newscientist.com/article/dn2943-brain-tumour-causes-uncontrollable-paedophilia.html

Some instances in which neuroscience (primarily neuroimaging) has been used as evidence include[33]:

- Neuroimaging evidence of the capacity to make a will[34].
- Neuroimaging evidence to establish that a defendant had a mental condition that rendered him unfit to plead at the time of his first trial[35].
- Neuroimaging to support claims that a personality change has occurred as a result of brain damage[36].
- In the USA, brain scan evidence has been introduced to argue that an individual's culpability should be mitigated, either because of brain abnormalities, or because of brain development (adolescence), but not in England and Wales.

In general, the admissibility of evidence in both criminal and civil trials is subject to quite complex rules. The admissibility of neuroscientific evidence would be subject to both the general rules for evidence and particular rules for scientific evidence. The Law Commission has recently recommended that such (expert) evidence should be admitted only if it is reliable, and it has proposed a multi-factor test to determine reliability (see Box 3).

Box 3: Admissibility of expert scientific evidence

Tests for admitting expert scientific evidence in civil cases and criminal cases seem, in practice, to turn on whether it is necessary to draw on experts, whether the evidence will assist the court, and, in particular, whether the evidence is reliable. It should be noted that the term reliability here means that the evidence can be relied upon to make a decision, rather than the scientific sense of repeatable across a number of experiments.

The Law Commission's report[37] on the admission of expert evidence in criminal cases outlines proposals to include a new reliability test. A long list of generic factors that bear on reliability includes the following:

- the quality of the data on which the opinion is based, and the validity of the methods by which they were obtained;
- whether any material upon which the opinion is based has been reviewed by others with relevant expertise (for instance, in peer-reviewed publications), and the views of others on that material;

33 Examples from Claydon and Catley 2011 *Neuroscientific evidence in the English Courts.* In: Spranger *et al.* (eds) *International neurolaw: a comparative analysis*. Springer: New York.
34 As in Carr and another v. Thomas [2008] EWHC 2859.
35 As in R v Mohammed Sharif [2010] EWCA Crim 1709.
36 As in Meah v Mcreamer [1985] 1 All ER 367.

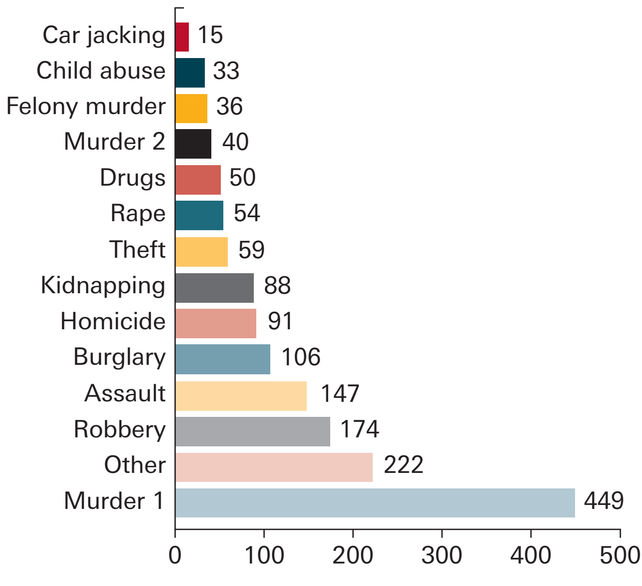
37 Law Commission 2011 *Expert evidence in criminal proceedings in England and Wales.* The Stationary Office. Available online at: www.official-documents.gov.uk/document/hc1011/hc08/0829/0829.pdf

- whether the opinion is based on material falling outside the expert's own field of expertise;
- the completeness of the information which was available to the expert, and whether the expert took account of all relevant information in arriving at the opinion (including information as to the context of any facts to which the opinion relates);
- whether there is a range of expert opinion on the matter in question; and, if there is, where in the range the opinion lies and whether the expert's preference for the opinion proffered has been properly explained; and
- whether the expert's methods followed established practice in the field; and, if they did not, whether the reason for the divergence has been properly explained.

4 Specific challenges facing the application of neuroscience to some key legal issues

This chapter explores specific areas in which neuroscience might have new insights to offer for the law. The intention is not to provide an exhaustive overview of every facet of the law in which neuroscience may provide some new information. Indeed, there are examples that we have been unable to cover within the scope of this study.[38] Nor do we wish to suggest that neuroscience *should* necessarily be used, or *will* definitely impact, in all of the examples we cite. It has been seen that neurological evidence

Figure 3. This chart shows cases in which neurological or behavioral genetics evidence is introduced in criminal cases on behalf of a criminal defendant. Based on cases in the USA in which neurological evidence is discussed in a judicial opinion. From 843 opinions (majority, plurality, concurrence, dissent), and 722 unique cases analysed between 2004–2009. Source: Professor Nita Farahany database 2011. Personal communication.



38 See for example research carried out in the UK and Belgium on consciousness of vegetative state patients: http://news.bbc.co.uk/1/hi/health/8497148.stm

is already being used in wide array of cases in the USA (see Figure 3), and it would be surprising if this trend did not continue.

4.1 Risk

Here the term 'risk' is used in the context of sentencing and probation, rather than prior to trial and conviction. Risk assessment is an assessment of probability – in this instance the probability of reoffending. It does not therefore claim to provide certainty. It is not possible to predict with certainty that one prisoner will reoffend within the next year if released, and another will not – risk is a prediction of likelihood on the basis of what is known about that individual or of what is known from data on other similar individuals in the past.

Risk assessments are made in relation to sentences of probation, in decisions as to the type of sentence to pass on a convicted offender or the length of a prison sentence, and on decisions to release prisoners after they have completed a certain portion of a prison sentence. However the problem of risk assessment has come into sharp focus since the indeterminate sentence for public protection was introduced in the Criminal Justice Act 2003. This enabled judges, not only to set a minimum tariff for a prison sentence, but to require the defendant to satisfy the authorities that he or she is fit for release and does not pose any threat to the community. These measures were initially designed as a measure to detain a small number of exceptionally dangerous individuals; however at the end of March 2011 there were a total of 6,550 Imprisonment for Public Protection (IPP) prisoners[39]. In the absence of any change in the law (which is indeed now mooted) this figure is predicted to increase yet further. Partly because of criticisms of detention based solely on the basis of an assessment of risk, which runs counter to many of the traditional principles of criminal law – that a person can only be detained for what they have done, not for what they might do in the future – the current Government has brought forward proposals to change sentencing policy that would end such indeterminate sentences[40].

It seems likely that many of these people would not in fact necessarily go on to reoffend if released. As has been documented by Monahan[41], those who make these decisions tend to err on the side of caution. This is perhaps unsurprising: there may be a perception that releasing someone who goes on to commit a further crime – especially if it is a violent crime, has more serious consequences (including adverse publicity) than keeping someone in prison who would not go on to reoffend. There is also an issue that is shared with other risk assessments – for it is more common to predict falsely that rare events will occur than to correctly predict their occurrence.[42]

39 www.justice.gov.uk/downloads/publications/statistics-and-data/mojstats/provisional-ipp-figures.pdf
40 BBC News *Ken Clarke's justice bill passed despite 'attacks'.* Available online at: www.bbc.co.uk/news/uk-politics-15565404
41 Monahan *et al*. *Rethinking risk assessment: The MacArthur study of mental disorder and violence.* Oxford University Press, 2001.
42 Szmukler 2001 *Violence risk prediction in practice*. The British Journal of Psychiatry **178**, 84–85.

Clinical and actuarial risk assessment

In the closing decades of the twentieth century, there was a move away from seeking to identify specific individuals who were inherently dangerous towards an assessment of levels of risk informed by multiple, changing environmental factors. This was partly because of the well documented inability of psychiatrists to predict future risky behaviour, classically discussed by Monahan and Steadman[43]. They argued that a dimensional approach to risk assessment should replace the binary classification of 'dangerous' or 'not dangerous'.

Models of risk assessment can be grouped into two broad categories. A clinical assessment will rely on the judgement of an individual or small group of experts about a particular individual. By contrast, an actuarial or statistical assessment will assign an individual to a particular group, based on the characteristics he or she shares with members of that group, and will calculate the risk of reoffending by the rate of reoffending in that group. The perceived virtues of each approach depend in part on the use to which such assessments are put: at least some psychiatrists, concerned to help or treat individuals, seem to favour a clinical approach[44], but many psychologists and criminologists would agree with Meehl that '66 years of consistent research findings [have come out] in favour of the actuarial method'[45].

It is sometimes argued that as actuarial assessment is based on information about groups of people, it cannot be straightforwardly applied to predict the behaviour of an individual (see Chapter 2.4 for further discussion of generalisation from group studies). However, that is not necessarily the case. For instance, someone who has already committed two violent crimes may be likely to commit a third if now released from prison. This may be more likely still if he or she comes from a family of violent criminals, was abused by his or her father as a child and dropped out of school at an early age. Why? Because it is known from compiling statistics that many people sharing these characteristics do reoffend.

It is not the job of this report to provide a critique of different models of risk assessment. It should be noted that, while psychological scales and checklists are used in some current risk assessment procedures, neuroscientific methods for assessing risk remain in the research stage, and are not currently used in practice. However, it is worth looking at some currently used instruments to consider whether there is any reason to believe that neuroscience might be used to improve them.

43 Steadman *et al.* 1993 *From dangerousness to risk assessment: implications for appropriate research strategies.* Mental Disorder and Crime 39–62, Sage Publications, Inc: Thousand Oaks, CA.

44 Mullen 2000 *Forensic mental health.* The British Journal of Psychiatry **176**, 307–311.

45 Grove and Meehl 1996 *Comparative efficiency of informal (subjective, impressionistic) and formal (mechanical, algorithmic) prediction procedures: The clinical-statistical controversy.* Psychology, Public Policy and Law **2**, 293–323.

Instruments for risk assessment

Tools used in the USA

In the USA, there is increasing use of formal actuarial risk assessment tools. These consist of checklists of factors associated with reoffending or danger to others, based on previous follow up studies of released prisoners. The condition for release or further detention is often defined in terms of a specific score on such instruments. There is good evidence from the USA that several such checklists, of which the best known is probably the Violence Risk Appraisal Guide (VRAG)[46], do indeed predict recidivism at above chance levels[47].

A study conducted in the city of Philadelphia[48] provides another example of a strictly actuarial approach to predicting whether criminals on probation or parole would murder or attempt to murder within two years of beginning their supervision. The results suggested that use of this model would have significantly improved the accuracy of risk assessment.

Tools used in the UK

In the UK, the National Offender Management Service sets standards and procedures for profiling offenders into different tiers of risk of future serious harm, using a system known as OASys (The Offender Assessment System). The decision is usually that of structured professional judgement informed by evidence from a variety of sources[49]. To the extent that a professional judgement is the final deciding factor, this would count as a clinical procedure. One study has reported that even when a clinician is provided with exactly the same information as is entered into an actuarial assessment, the clinical judgement will be less accurate than the actuarial one[50].

A role for neuroscience?

Is it possible that evidence from neuroscience or behavioural genetics could one day be used, along with existing techniques, to increase the accuracy of risk assessment? Might it be possible to find neurobiological markers of a propensity to violent or impulsive behaviour that could be used in decisions about probation and parole? Whilst such identification might not of itself be accurate enough to make a decision on the fate of an individual when taken alone, it might be useful in combination with other information in the

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46 Quinsey *et al.* 2006 *Violent offenders: Appraising and managing risk* (2nd ed.). American Psychological Association: Washington, DC.

47 There are several different instruments that have been used – all seeming to be more or less equally effective. For a recent review, see: Yanget *et al.* 2010 *The efficacy of violence prediction: A meta-analytic comparison of nine risk assessment tools*. Psychological Bulletin **136**, 740–767.

48 Berk *et al.* 2009 *Forecasting murder within a population of probationers and parolees: a high stakes application of statistical learning.* Journal of the Royal Statistical Society 172, 191–211.

49 These include static risk factors (such as age and previous convictions) and dynamic risk factors (around areas including accommodation, education, income and relationships). See Debedin 2009 *A compendium of research and analysis on the Offender Assessment System (OASys) 2006–2009.* Available online at: www.justice.gov.uk/publications/docs/research-analysis-offender-assessment-system.pdf.

50 Hilton, N. Z., & Simmons, J. L. 2001 *The influence of actuarial risk assessment in clinical judgments and tribunal decisions about mentally disordered offenders in maximum security.* Law and Human Behaviour **25**, 393–408.

assessment of risk. In addition, evidence from neuroscience or behavioural genetics might help to provide a basis for effective treatment or rehabilitation.

Neuroimaging

Both structural and functional MRI studies have revealed differences in the brains (particularly in the amygdala and orbitofrontal cortex) of people convicted of certain types of violent offences, or diagnosed as psychopaths, when compared to control subjects. While offences committed by individuals diagnosed with psychopathy are a small proportion of all offences[51], people diagnosed as psychopaths or with antisocial personality disorder commit a disproportionate number of crimes compared to their number in the general population. Some researchers have argued, on the basis of brain imaging, that characteristics predictive of such behaviour may be detected in children as young as seven who engage in antisocial behaviour[52]. That there are some differences in the structure and functioning between the brains of people diagnosed as psychopaths and those who are not should really not come as a surprise: if they behave differently, it is only to be expected that such behavioural differences will be somehow related to brain processes or structural variations in the brain. But it is important to remember the caveat about generalising from groups to individuals, as discussed in Chapter 2.4: an average difference between two groups does not mean that all members of one group can be distinguished from all members of the other.

As also outlined in Chapter 2.4, imaging studies can only establish a correlation between brain structure or activation and a behavioural outcome; they cannot prove that the difference in the brain is the cause of the behaviour, let alone that the behaviour would occur in other environments. Furthermore, given what is known about environmental influences on neural development, it is always possible that the difference is at least in part a consequence of an adverse early environment.

However, risk assessment is concerned with predicting behaviour, which does not necessarily require the identification of cause. So the critical question is whether any differences revealed by imaging studies are either better predictors of recidivism than the score on a checklist, or even, if they are not, whether they would increase the accuracy of any such prediction if used in conjunction with other behavioural measures. At present this is unknown because the relevant studies have not been conducted.

Behavioural genetics

Some dozen twin studies, several with samples of over 2,000 twins, have suggested that there are genetic influences

51 One survey of prisoners in England and Wales found a prevalence of categorically diagnosed psychopathy of 7.7% in men and 1.9% in women. (Coid *et al.* 2009 *Psycopathy among prisoners in England and Wales.* International Journal of Law and Psychiatry **32**, 134–141).

52 Raine *et al.* 2010 *Neurodevelopmental marker for limbic maldevelopment in antisocial personality disorder and psycopathy. British Journal of Psychiatry* **197**, 186–192.

on propensity to violent and anti-social behaviour[53]. But, however strong the evidence for the heritability of antisocial behaviour, it will not necessarily help assess the risk that a particular individual will reoffend when released from prison. Evidence of heritability merely establishes that some of the differences between people in antisocial behaviour are associated with genetic differences between them. It does not tell us how such genetic differences are associated with behavioural differences (they almost certainly interact with environmental differences), nor how many and which particular genes are involved. As Viding *et al.* note[53], none of these twin studies has provided any convincing answer to these questions, and without such answers they can tell one nothing at all about the individual case.

No doubt future research will eventually identify some of the genetic variants associated with differences in antisocial behaviour (although it may also be found that these same variants are also associated with traits considered valuable), but it always needs to be stressed that there are no genes for particular conditions such as psychopathy. At best, the presence of one allele of a gene rather than another may increase the probability of antisocial behaviour, but the history of genetic research into complex patterns of human behaviour says that the probable outcome of future research will be that there are many such genes, each with only a small effect, and there will be many different pathways leading to the same behavioural outcome (antisocial behaviour)[54].

One example of a single allele that does, however, appear to have a significant effect on violent behaviour is the gene encoding the neurotransmitter-metabolising enzyme monoamine oxidase A (MAOA). Low levels of MAOA have been found to be associated with aggressiveness of young boys raised in abusive environments[55]. Furthermore, differences in amygdala and orbitofrontal activity have been observed in subjects with different variants of the MAOA gene when looking at threatening pictures[56]. This evidence has been used to reduce a convicted murderer's sentence[57]. Although such decisions have been questioned, the present issue is whether such genetic evidence could or should be used to inform decisions about parole or release from prison.

If risk is a prediction of likelihood on the basis of what is known about that

53 Viding *et al.* 2011 *Quantitative genetic studies of psychopathic traits in minors: Review and implications for the law*. In Kiehl and Sinnott-armstrong (eds.). *Psychopathy and Law.* Oxford University Press.

54 Eisenberger *et al.* 2007 *Understanding genetic risk for aggression: clues from the brain's response from social exclusion.* Journal of Biological Psychiatry **61**, 1100–1108.

55 Caspi *et al.* 2002 *Role of genetype in the cycle of violence in maltreated children.* Science 297, 851–854. Replicated in Fergusson *et al*. 2011 *MAOA, abuse exposure and antisocial behaviour: 30-year longitudinal study.* British Journal of Psychiatry **198**, 457–463.

56 Meyer-Lindenberg *et al.* 2006 *Neural mechanisms of genetic risk for impulsivity and violence in humans.* Proceedings of the National Academy of Sciences **103**, 6269–6274.

57 Feresin 2009 *Lighter sentence for murderer with bad genes.* Available online at: www.nature.com/news/2009/091030/full/news.2009.1050.html

individual or of what is known from data on other similar individuals in the past, genetic evidence might in principle be used in combination with other risk assessment information. Thus if it turns out that the combination of this particular allele of the MAOA gene and a history of earlier abuse really does significantly increase the probability of future violent and criminal behaviour, then its use might be justified in decisions about risk assessment in an actuarial system, and, in decisions as to the kinds of sentence that might reduce the chances of reoffending.

4.2 Deception

The potential to detect deception is one of the more commonly cited areas in which neuroscience may impact on the law.[58,59]

Functional imaging experiments with students have shown differences in neural activity when they are telling the truth and when they are lying[60]. Differences are often found in areas of prefrontal cortex that, in other experiments, have been shown to be activated when people are engaged in some cognitive effort or choosing between alternative actions. This suggests the possibility that their activation may be correlated with suppressing the truth and fabricating lies. But it is *certainly* not uniquely indicative of any such thing, and different experiments have been quite inconsistent in which brain areas are activated when lying[61].

The apparent success of these studies has encouraged neuroscientists to set up commercial companies to market MRI-based lie detectors, such as Cephos and NoLie MRI. Such experiments may be a necessary first step in trying to establish a useful fMRI or EEG lie detector. But they are only a very small step. There are many obvious problems, such as the fact that studies of college students may not generalise to those such as psychopaths who are habitual and skilful liars. The typical procedure is to *instruct* participants to lie in answer to some questions and tell the truth in answer to others (which is hardly what happens in a court of law) – although there is one published study in which some participants, but not others, *chose* to lie (no doubt believing they could get away with it) for financial gain[62].

But there are also some seemingly insuperable problems:

- Someone accused of a crime who has undergone prolonged interrogation may come to believe their own protestations of innocence even if they are in fact guilty. They then have no need to inhibit the truthful response when they deny their guilt, because they believe they *are* responding

58 http://news.bbc.co.uk/1/hi/health/8722182.stm
59 For a broad discussion see Stern 2002 *The polygraph and lie detection: Report of the National Research Council Committee to review the scientific evidence on the polygraph.* National Academies Press: Washington DC.
60 Bles & Haynes 2008 *Detecting concealed information using brain-imaging technology*. Neurocase **14**, 82–92.
61 Farah *et al.* 2008 *Brain imaging and brain privacy: A realistic concern*. Journal of cognitive neuroscience **21**, 119–127.
62 Greene and Paxton 2009 *Patterns of neural activity associated with honest and dishonest moral decisions.* Proceedings of the National Academy of Sciences **106**, 12506–12511.

truthfully. In such a situation, a 'lie detector' based on brain imaging signals will yield a negative result, even though the defendant's statements are in fact untrue. In experiments with face recognition (described below in section 4.3), fMRI signals were comparable whenever the participants *believed* that they had seen a particular face before, whether they had or not[63]. It is likely therefore that the same will be true when a defendant believes that they are telling the truth when they are not.

- Conversely, as soon as you know that lying is associated with activity in regions of the brain associated with cognitive effort, it might be a relatively simple matter to produce a false positive reading when you are actually answering a particular question truthfully. People can indeed be taught countermeasures that will defeat an fMRI lie detector: in one experiment, the success rate for distinguishing truth from lies dropped from 100% to 33% when participants used countermeasures[64].

- Even if fMRI can detect an increase in activity in certain regions of the brain when a subject is lying, this does not mean that if such an increase in activity is observed, then the participant must be lying. See Chapter 2.4 for discussion of the 'reverse inference' problem.

There are examples of defendants voluntarily undergoing brain imaging to prove their innocence. In one case that went to a pre-trial hearing, the company Cephos presented fMRI evidence purporting to show that a 60-year-old defendant was telling the truth when he denied that he had conspired to defraud the US federal government. On the first test, it was claimed that the results showed the defendant was being truthful. A second test suggested that he was not, and a third test was run which the defendant again passed successfully. Perhaps unsurprisingly, Judge Tu Pham ruled that the fMRI evidence did not pass the test for admissibility in court[65]. But even if the evidence had been more consistent, for the reasons given above, for the foreseeable future reliable fMRI lie detection is not a realistic prospect.

4.3 Memory

It has so far proved difficult to apply neurobiological approaches to memory within a legal context, but with continual advancements, this may change.

Any memory system needs to encode or input information, to store and in due course to retrieve it. Encoding depends on the focus of attention; if detail is not noticed it will not be encoded and hence not stored. Information must be stored to be maintained over time. More information

63 Rissman *et al.* 2010 *Detecting individual memories through the neural decoding of memory states and past experience.* Proceedings of the National Academy of Sciences **107**, 9849–9854.

64 Ganis G, Rosenfeld J.P., Meixner J., Kievit R.A. & Schendan H.E. 2011 Lying in the scanner: Covert countermeasures disrupt deception detection by functional magnetic resonance imaging. NeuroImage **55** (1), 312–319.

65 Miller G 2010 *fMRI lie detection fails a legal test*. Science **328** (5984), 1336–1337.

is stored than can be accessed or retrieved at any given moment.

Psychological research on memory has established a number of findings concerning the reliability of a witness's testimony[66]. For example:

- Human memories are good at extracting the gist of an event, but tend to discard the sort of detail that might be highly relevant in court.[67]
- People retain very few memories before the age of five, so called infantile amnesia. Beyond this age, children can be a valuable source of information, given appropriate interview methods. Memory for specific events tends to improve up to the late teens and gradually declines, with a steeper decline beyond the age of 60.[68]
- Memory of a traumatic event may be intrusive as in the case of flashbacks in post traumatic stress disorder. In other cases, the traumatic event may fail to be retrieved, which may or may not be intentional. High levels of emotion may also reduce the capacity of the witness to recall detail.[69]
- Memory tends to decline over time, particularly for detail. There is a greater likelihood of forgetting specific details for a particular event when similar events have occurred either before or after the event in question.[70]
- The process of interviewing a witness can interfere with memory, particularly if leading questions press the witness to come up with inaccurate memories. For instance, people asked whether broken glass was present when two cars 'crashed' are less likely to falsely report that there was broken glass if 'crashed' is replaced by a word that does not imply that there probably was broken glass, such as collided . False memories are particularly likely to occur in situations of heightened suggestibility (eg in therapy), and when memories are sought from many years ago, as in some memories of child abuse.[71,72]

A great deal of research into the factors influencing retrieval has been carried out in recent years, and has been built into the Cognitive Interview, a method of optimising the accurate retrieval of information from witnesses. This procedure is now widely used in the UK, owing to successful collaborations between academics and the police which

66 Fisher 2011 *Special Issue on Psychology and the Law*. Current Directions in Psychological Science **20**.
67 Yuille & Cutshall 1986 *A case study of eyewitness memory of a crime*. Journal of Applied Psychology **71**, 291–301.
68 Nilsson *et al.* 2004 *Betula: A prospective cohort study on memory, health and aging.* Aging, Neuropsychology and Cognition **11**, 134–148.
69 Kopelman 2002 *Psychogenic amnesia*. In Baddeley, Kopelman and Wilson (eds.), *Handbook of Memory Disorders* (2nd ed., pp. 451–472). Wiley: Chichester.
70 Baddeley 2001 *Human memory: theory and practice* (Revised ed.), 169–190. Psychology Press: East Sussex.
71 Ceci & Bruck 1993 *Suggestibility of the child witness: A historical review and synthesis*. Psychological Bulletin. **113**, 403–439.
72 Geraerts *et al.* 2007 *The reality of recovered memories: Corroborating continuous and discontinuous memories of childhood sexual abuse*. Psychological Science **18**, 564–568.

have led to improved methods for interviewing children. Research on face recognition has also led to methods that, in the UK at least, have highlighted the danger of relying too heavily on uncorroborated face recognition evidence. At the same time, methods of interviewing witnesses about the facial characteristics of participants have been improved and methods of optimising the collection of information from line-ups have been developed.

False memories

The law is concerned about the reliability of eyewitness testimony, and for example whether recollection of childhood abuse is truthful. While psychologists have contributed many valuable insights in this area, the question is whether neuroscience may contribute even more, for instance through the use of brain imaging studies to determine whether a reported memory is true. A case in India was widely reported as an example of EEG being used as evidence of 'guilty knowledge' in the courts. However, the conviction was overturned on appeal, and the EEG testing used was not referenced in the Judge's summing up in the appeal case.[73]

Experiments have been conducted in which people look at a series of pictures of faces or words and are then asked to say whether a particular face or word appeared in the list. These reveal differences in neural activity when participants correctly identify a face/word as one they had been shown before, and correctly identify another one as one that is new to them. However, fMRI gave the same reading whenever the participant *believed* that the face had not appeared in the original list, whether they had seen the face or not[74]. A small but unreliable difference was observed between instances when the participant correctly or incorrectly believed that they had seen the face before. But in all these experiments the interval between studying a list and being asked to identify old and new faces or words was of the order of a few minutes. It remains to be seen whether this difference would persist when the interval between study and test was several days or weeks. It seems rather probable that it would not: if it did not, as with 'lie detection', the finding would be of little practical relevance.

Memory erasure

It is known that actions performed whilst certain drugs are acting on the brain will be forgotten. In theory, it may also one day be possible to prevent the formation of memories either shortly after an action has taken place, or after a memory has been recalled, through the use of drugs that prevent the synthesis of key proteins in memory formation. If this were possible, it might have implications for the law – for instance, in seeking to 'erase' a memory of criminal activity. Equally the victim of an

73 Giridharadas 2008 *India's use of brain scans dismays critics.* New York Times 15 September 2008. Available online at: www.nytimes.com/2008/09/15/world/asia/15iht-15brainscan.16148673.html?pagewanted=all

74 Rissman *et al.* 2010 *Detecting individual memories through the neural decoding of memory states and past experience.* Proceedings of the National Academy of Sciences **107**, 9849–9854.

horrific incident might seek to erase a painful memory, thereby mitigating their pain and distress but with the consequence of being thereby rendered unable to assist the investigation into what happened or give evidence in court. A problem would be the balance to be struck between victim protection and the demands of due process of law. At present, however, as such protein synthesis inhibitors have dangerous side effects this cannot be tested on human participants. It is worth noting, however, that some work has been done on potential agents for the treatment of Post-Traumatic Stress Disorder (PTSD) to dampen traumatic memories.[75] For instance, propranolol has been shown to reduce the strength of emotional memories when they are recalled.[76,77]

4.4 Pain

Much is now known about the neurological basis for pain, but the latest findings are not widely known or understood, including in some parts of the legal and medical professions where key insights may soon be of practical relevance.

In many civil cases, lawyers are interested in whether a claimant's pain is real or exaggerated, and if the latter whether this is due to 'malingering' or other more complex mechanisms (as detailed above). However, medical witnesses may not be experts in chronic pain and may not have an up to date understanding of the relevant neuroscience, such that some medical witnesses equate observed structural damage to what the patient 'should feel'. Scientific understanding of pain suggests that this is not correct.

The Judicial Studies Board's Guidelines for the assessment of general damages (meaning pain, suffering and loss of amenity) in personal injury cases are now in their 10th edition. The law continues to develop in this area at such a pace that the work is updated in loose-leaf form twice a year.

Pain is a sensation felt in parts of the body that serves an essential purpose in the avoidance of harm. Pain has been defined as *an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*[78]. An important aspect of this definition is that pain is not necessarily caused directly by tissue damage – if a person reports that they are in pain, this should normally be accepted. Pain is a private experience that is a direct result of processing mechanisms in the brain.

75 This will be briefly discussed in the forthcoming Module of the Brain Waves project on neuroscience, conflict and security.

76 Brunet *et al.* 2011 *Trauma reactivation under the influence of propanolol decreases posttraumatic stress symptoms and disorder.* Journal of Clinical Psychopharmacology **31**, 547–550.

77 Kindt *et al.* 2009 *Beyond extinction: erasing human fear responses and preventing the return of fear*. Nature Neuroscience **12**, 256–258.

78 International Association for the Study of Pain : Part III: Pain Terms, A Current List with Definitions and Notes on Usage (pp 209–214) Classification of Chronic Pain, Second Edition, IASP Task Force on Taxonomy, edited by H. Merskey and N. Bogduk, IASP Press, Seattle, ©1994.

There are different types of pain. Acute, short term pain begins when specialised sensory receptors called nociceptors detect environmental stimuli that may cause tissue damage. A signal in the nociceptors is transmitted to the brain for further processing. As this signal is transmitted through the peripheral nervous system, spinal cord and brain (the 'pain neuraxis'), it can be significantly modulated; the signal can be made stronger, weaker, or even qualitatively altered. The signal that arrives at and is further processed by the brain can therefore be very different from the one that began. This means that the pain described by the subject may be very different from the pain that an observer might predict. Chronic, long term pain differs from acute short term 'warning' pain. Different mechanisms in the 'pain neuraxis' exist to cause acute pain to shift to chronic pain, and for chronic pain to be maintained.

Key implications are that:

- Pain may be genuinely reported, even in the absence of visible or detectable damage to tissue, or underlying disease that might help explain it.
- The level of pain that an individual experiences is difficult to predict and is rarely linearly related to the extent of tissue damage.
- Individuals' experiences of pain can be changed by many different factors; for example anxiety, depression, attention and physiological changes can all alter brain processing just as much as causing more or less severe tissue damage.

Functional imaging methods now make it possible to identify which brain regions become active during a painful experience, and to relate this to an individual's specific pain experience. It is possible to show how pain processing mechanisms can be influenced by factors such as anxiety, depression, and other conditions. Whilst these technologies are not at present able to establish whether a particular individual is genuinely experiencing pain (see section 2.4) or is malingering, it is important that future developments are relayed to the legal profession, and to medical expert witnesses. Such techniques are currently being used for diagnostic purposes to guide treatment and surgery, and so it is conceivable that this information will one day be used in courts of law. If it is, however, it will be important to guard against the possibility that people may be able to use countermeasures to simulate the experience of pain (see section 2.4.5)

4.5 Non-Accidental Head Injury (NAHI)

One area of neuroscience of immediate relevance for the law is in cases of Non-Accidental Head Injury (NAHI) in babies and infants, or Shaken Baby Syndrome (SBS).This is a controversial area in which there has been disagreement among those giving expert evidence as to the cause of the injuries.

4.5.1 Diagnosis

When an adult holds an infant by the torso and violently shakes him, the brain impacts repeatedly on the front and back of the skull. The brain swells as a consequence of this trauma and the bridging veins (the small capillaries that exist between larger vessels) rupture. The blood released forms a thin film over the infant's brain. The retinas at the back of the eyes also begin to bleed and damage is inflicted to the nerve cells of the brain stem and neck.

The injuries caused by shaking are often the result of a momentary act of violence. No more than a few seconds of shaking are needed to produce permanent brain damage or to prove fatal. The sentences for those convicted of manslaughter in instances of NAHI are significant.

A triad of components is considered necessary for the forensic diagnosis of NAHI, and pathologists are trained to look for these three factors during post mortem examination of the baby:

- Encephalopathy, usually in the form of swelling of the brain and hypoxic ischaemia (when the brain is deprived of blood and oxygen).
- Subdural haematoma (bleeding under the membrane surrounding the brain).
- Retinal haemorrhage (bleeding at the back of the eyes).

4.5.2 Consensus?

Although the observation of all three components of the triad, seen in the light of other clinical features, such as an absence of signs of external injury to the head, is considered by many pathologists good evidence of NAHI, this conclusion has been disputed by some who have argued that there are other means, apart from abuse, by which these types of injuries can arise, for example that hypoxia arising from other causes might be responsible for the other symptoms of the triad. They point to the typical lack of independent witnesses in alleged NAHI cases and therefore the lack of definitive evidence that abuse has occurred.

The Royal College of Pathologists convened a meeting in 2009 to discuss these issues. The report of this meeting concluded that the existence of the triad provided a strong *prima facie* case for suspecting NAHI, but might not be sufficient in all cases to prove it. One important factor was the age of the baby: in infants only a few days old the triad might reflect problems arising during birth; but this was much less likely in babies several months old.

The meeting heard a report of a relatively large study at King's College Hospital in which apparent NAHI cases were compared both to control cases where there was evidence only of hypoxia and ischaemia, and to others where there was independent evidence of abuse or accidental injury. The NAHI cases were clearly differentiated from the control cases, but resembled those where there was independent evidence of injury. It was also reported that in addition to the triad there was evidence that damage to the medulla also seemed to discriminate between the control cases and the others.

While this study may not be definitive, the meeting agreed that efforts should be made to follow it up with an even larger sample of paediatric deaths from a variety of causes. It is clear that this will be the only way to secure wider agreement, and to enable criminal and family courts to obtain the right and just result in these complex and important cases. It will be important to overcome any obstacles standing in the way of such research being carried out.

5 Recommendations

Neuroscientists know much more about the brain than they did thirty years ago, and it can be expected that within the next thirty years they will know even more. Together with other approaches, insights from neuroscience can help explain behaviour and the mind, which might be helpful in adding to the existing methods used in the law for interpreting and predicting behaviour.

There is no doubt that advances in neuroscience have had, and will have, an important impact on the law. For example, in areas such as pain research and neuropathology in Non-Accidental Head Injury (NAHI) cases, neuroscience is expected to have *some* impact on the law, even if the nature and full extent of the insights from research are as yet unclear. That said, neuroscience is unlikely to fundamentally alter key legal concepts such as responsibility, and it is likely to be effective only when used in conjunction with other disciplines such as behavioural genetics, psychology, behavioural sciences and sociology.

Many of the issues around neuroscience and the law that have been discussed in this report also apply to the intersection of science and the law more generally. The recommendations that follow below are focused on neuroscience; however some of the principles might be applied more widely.

5.1 Bridging the gap

There is a big gap between research conducted by neuroscientists and the realities of the day to day work of the justice system. Neuroscientists and legal professionals conduct their work in different surroundings, using different methodologies and language. There is currently no forum in the UK for bringing together the two groups to explore areas of mutual interest[79]. Some lessons might be learnt here from other countries, for instance in the USA where programmes have brought together neuroscientists and lawyers for over a decade.

Recommendation 1: An international meeting should take place every three years to bring together those working across the legal system with experts in neuroscience and related disciplines. The aim of this meeting should be to discuss the latest advances in areas at the intersection of neuroscience and the law to identify practical applications that need to be addressed.

Recommendation 2: The systems used by legal professionals to identify, access and assess the quality of expertise in specific scientific areas should be reviewed by the judiciary and the Bar Council to ensure the latest advice is made available. This should be carried out in consultation with learned societies such as the British Neuroscience

79 This might be contrasted with the situation in the USA, where several initiatives are in existence. For instance, the John D. and Catherine T. MacArthur Foundation funded Law and Neuroscience project which has been underway since 2007; the work of the National Academy of Sciences Committee on Science, Technology and the Law and Federal Judicial Center; and the Baylor College of Medicine Initiative on Neuroscience and the Law.

Association, and other specialist societies as appropriate.

5.2 Training and Education

It is important that professionals at all stages of the legal system who might encounter neuroscience understand some of the key principles on which it is based; the limitations to what studies can tell us; and some of the generic challenges of its application. This report is intended as a short first step in that regard. However, lawyers and judges in England and Wales often have no training in scientific principles and may benefit from some basic instruction. Similarly, undergraduates in neuroscience are not necessarily taught about the societal implications of the discipline.

Recommendation 3: University law degrees should incorporate an introduction to the basic principles of how science is conducted and to key areas of science such as neuroscience and behavioural genetics, to strengthen lawyers' capacity to assess the quality of new evidence. Conversely, undergraduate courses in neuroscience should include the societal applications of the science.

Recommendation 4: Relevant training should be made available where necessary for judges, lawyers and probation officers. This should count towards Continual Professional Development (CPD) requirements for lawyers, and for judges might be administered through the Judicial College's programme of seminars.

5.3 Building applied research capacity

Almost all neuroscientific research in the UK is related to health. Research programmes are not yet targeted to other areas, such as education and the law, where the policy implications could be just as significant. However, findings from research do have wider potential implications. For instance research conducted on the neurological basis of pain (with the aim of managing chronic pain more effectively) may have implications for welfare and personal injury claims. This report has highlighted a number of areas in which further research would provide important insights for the law.

Recommendation 5: Further research is needed on areas including:

- The National Institute for Health Research (NIHR) should encourage neuropathology studies to characterise Non-Accidental Head Injury (NAHI) and distinguish it from accidental or natural causes.
- The Economic and Social Research Council (ESRC) should encourage studies into the relative efficacy of different models of risk assessment in the context of probation, and a possible role for neuroscience to be used in combination with existing approaches.

6 Further reading

This document provides a brief introduction to some areas of neuroscience and the law. There are areas such as the detection of consciousness in Persistent Vegetative State (PVS) patients, prognosis for accident victims and addiction that have not been discussed within this report. For those interested in exploring further the issues raised, the following sources are recommended in addition to the specific references cited throughout the report:

Farahany Nita A (ed) 2009 *The Impact of Behavioural Sciences on the Criminal Law*. Oxford University Press.

Jasanoff 1997 *Science at the bar: law, science and technology in America.* Harvard University Press.

MacArthur Neurolaw project: http://lawneuro.typepad.com/

Michael Freeman (ed) 2011 *Law and Neuroscience* Oxford University Press.

Owen *et al.* 2006 Detecting awareness in the vegetative state. Science **313**, 1402.

Reference Manual on Scientific Evidence, Third Edition. The National Academies Press: Washington, D.C.

Sinnott –Armstrong Walter & Nadel Lynn (eds) 2011 Conscious Will and Responsibility. Oxford University Press.

Spranger, Tade M. and Wagmann, Henning (eds) 2011 *International Neurolaw a Comparative Analysis*. New York:Springer.

Zeki & Goodenough (eds) 2004 *Law and the Brain.* Theme issue of Philosophical Transactions of the Royal Society B.

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ISBN: 978–0–85403–932–6
Issued: December 2011 Report 05/11 DES2420

Founded in 1660, the Royal Society is the independent scientific academy of the UK, dedicated to promoting excellence in science

Registered Charity No 207043

ISBN 978-0-85403-932-6
9 780854 039326

Price £20