

The Future of Neurolaw

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Over a decade ago Joshua Greene and Jonathan Cohen in their seminal article wrote: 'For the law, neuroscience changes nothing and everything'.^[2] Scholarly interest in the intersection between law and neuroscience is developing very quickly. This is demonstrated by this graph produced by the MacArthur Foundation's Research Network on Law and Neuroscience.^[3]

It is also clear that the investment in the brain sciences is currently immense. In 2012 the ten year budget of the European Union's Human Brain Project was estimated at €1.19 billion.^[4] President Obama launched the USA's BRAIN^[5] Initiative in 2013 by pledging \$100 million of State funding for the coming year with a similar amount pledged for each of the next ten years by private donors.^[6] The focus on brain research is not new - the then President of the United States, George Bush, had declared the 1990s 'the Decade of the Brain'.^[7] Whereas the aim of the Decade of the Brain was to 'enhance public awareness of the benefits to be derived from brain research',^[8] the aims of the Human Brain Project and of the BRAIN Initiative are to provide public and private money to take that brain research forward.^[9] The question for the law and for society more generally is what will that research find and what will be the implications of those findings.

1. THE CURRENT SITUATION

Neuroscience is already appearing in the courtroom. In England and Wales, a claimant seeking damages for a brain injury will, commonly, call neuroimaging evidence not just to prove the injury suffered, but also to inform the prognosis in terms of likely impact on future earning potential and likely future need for care and rehabilitation.^[10] Similarly, prosecutors will call neuroscientific evidence to prove the likely cause of injury to victims^[11] or to assess the extent of injury: issues that can be critical in determining the appropriate charge and the maximum potential sentence.^[12] The number of US cases in which neuroscientific evidence is used has been calculated as having doubled from 2006 to 2009.^[13] Indeed, in the United States it is fast approaching a situation where defence attorneys would be potentially negligent if they failed to gather brain scan evidence for a client facing a capital sentence.^[14] The United States is not the only country in which defence teams will make use of brain scan evidence. Parallel research in the United States,^[15] the Netherlands,^[16] Singapore,^[17] Canada^[18] and in England and Wales^[19] found defence lawyers in all jurisdictions making use of neuroscientific evidence to support their clients.

The English research found 204 reported cases in the eight-year period from 2005-2012 in which those representing people accused of criminal offences attempted to make use of neuroscientific evidence. In cases of alleged non-accidental head injury and sudden infant death syndrome^[20] neuroscientific evidence has been critical in over-turning convictions for murder^[21] and reducing convictions from murder to manslaughter.^[22] This type of evidence has not been restricted to injuries to children. In *Halling*^[23] scan evidence of the victim was introduced to try to argue that the fatal head injury had been sustained in self-defence.^[24] Neuroscientific evidence has also been introduced in the English courts to challenge the reliability of witness testimony. In *R v X*^[25] a conviction was ruled unsafe following evidence from an expert witness for the appellant that 'during the first five years of life, the frontal lobes of the brain rapidly change and that material was not retained in memory'.^[26] This has the effect that childhood memories are 'qualitatively different from later memories'.^[27] However, subsequently the Court of Appeal has ruled that research in this area is not sufficiently advanced and has excluded expert evidence on the reliability of childhood memories.^[28] This illustrates the problems for the law in deciding whether or not to admit expert evidence in areas where there is not yet consensus. On the one hand it can be argued that unreliable and unverified evidence should be excluded. On the other hand, there is a need for the law to keep abreast of scientific developments, otherwise the exclusion of evidence may lead to injustice. The comment of Judge LJ on expert evidence in *R v Cannings* is particularly apposite:

"We cannot avoid the thought that some of the honest views expressed with reasonable confidence in the present case (on both sides of the argument) will have to be revised in years to come, when the fruits of continuing medical research, both here and internationally, become available. What may be unexplained today may be perfectly well understood tomorrow. Until then, any tendency to dogmatise should be met with an answering challenge."^[29]

The English research suggests that neuroscientific evidence on behalf of those accused is more commonly introduced where the offence charged is a serious offence carrying a lengthy maximum sentence.^[30] The evidence is used to support appeals against conviction^[31] and appeals against sentence.^[32] Whilst the neuroscientific evidence is very significant in some cases,^[33] in a majority of the appeals against conviction examined the appeal failed.^[34]

The research from the United States presents a similar picture, the number of cases identified is greater, but very broadly in line when relative populations are taken into account.^[35] In both England and Wales and in the USA where specific neuroimaging technologies were mentioned as having been undertaken the type of scan most commonly used in both jurisdictions were Magnetic Resonance Imaging (MRI) and Computerised Tomography (CT or CAT scans) suggesting that the use of structural neuro-images in the courtroom is much more widespread than the use of functional neuroimaging.

The term 'neurolaw' dates back to at least 1991.^[36] The use of the term can be linked to other disciplines which have similarly had the prefix "neuro" added.^[37] The term neurolaw suggests a new type of law. However, at present, this is probably not warranted. It can be said that neuroscience, particularly cognitive neuroscience, is having an impact on the law, but it is not yet transformative. Advances in brain sciences are having an impact in assisting legal systems in assessing the seriousness of brain injuries, their causes and the likely prognosis of those who have sustained them. Neuroscience is helping to assess criminal responsibility and mental capacity as

well as being used to assess risk. However, whilst useful, this is not 'changing everything' to use the words of Greene and Cohen. The question that will be explored in the rest of this article is whether neuroscience and in particular cognitive neuroscience could transform the law.

2. FREEWILL

Greene and Cohen's celebrated essay looks, inter alia, at freewill and questions whether our conception that we make choices can survive advances in neuroscience.^[38] From a hard determinist standpoint freewill is an illusion. All events are the results of prior causes operating according to the laws of nature.^[39] Every event is causally determined - including human action. The idea of an uncaused causer has no place in this world view. For the law such a world view is potentially very challenging. Law and in particular the criminal law is built on the assumption that individuals normally have choice and that they are to be judged on the basis of the choices that they make. This is not a new phenomenon, in the mid eighteenth century Blackstone wrote:

'the concurrence of the will, when it has the choice either to do or to avoid the fact in question, being the only thing that renders human actions either praiseworthy or culpable. Indeed, to make a complete crime, there must be both a will and an act.'^[40]

This idea of both a will and an act can be seen in the requirement for most crimes of both a physical act (*actus reus*) and a mental element (*mens rea*), but Blackstone's statement also importantly has a focus on choice. This belief in a capacity of the individual to make choices remains a central underpinning of the law. Two hundred years after Blackstone, Hart wrote: 'unless a man has the capacity and a fair opportunity or chance to adjust his behaviour to the law its penalties ought not to be applied to him.'^[41] More recently the Law Commission for England and Wales have stated that: 'A person with no possibility of making any choice - whose action is in that sense "automatic" - does not have the capacity to control his or her actions.'^[42] In the view of the Law Commission such a person should be entitled to a defence to any criminal charge.^[43]

If hard determinists are correct then nobody has choice. Benjamin Libet's experiment is often cited as evidence that our belief that we choose is an illusion.^[44] In the experiment the participant has electroencephalogram (EEG) electrodes attached to her scalp. She sits in front of an oscilloscope timer and presses a button when she feels the urge to do so. She then records where the timer hands were when she first felt the urge to press the button. The experiment found that brain activity preceded the participant's perception as to when she first felt the desire to press the button. On average the brain activity took place 350 milliseconds (ms) before the participant reported starting to feel the urge to press the button. Whilst the test has been replicated, the interpretation of its findings remain controversial: with many objecting to an interpretation that the test demonstrates that free will is an illusion.^[45] Proponents of a belief that we have choice in whether or not to act can point to the fact that according to Libet's findings there is a further delay (on average 150 ms) between the reported timing of the first urge to press the button and the actual pressing of the button.^[46] This allows, it is argued, for an opportunity to veto the action. Therefore, whilst Libet's findings may (or may not) challenge a belief in free will they do create the possibility of creating a belief in 'free won't' (i.e. an ability to veto action). If we return to the definitions of Blackstone, Hart and the Law Commission this opportunity to control actions, preserved by this interpretation of Libet's experiment, is enough to retain a belief that we normally have choice and the corollary that in such circumstances it is normally^[47] justifiable to hold us responsible for those choices.

For the present, it would appear that the neuroscience of free will won't force the law to reassess its underlying approach to imposing responsibility. Scientists may on occasion say that there is no such thing as free will^[48] but this does not mean that law must abandon its assumption that acts are normally voluntary acts. The scientific debate continues with some taking compatibilist^[49] and some taking incompatibilist^[50] standpoints. At some point a consensus may emerge, but for the moment that does not seem imminent. If a consensus supporting hard determinism does emerge it may challenge mankind's innate feeling that we do make decisions. Our current beliefs may not be evidenced by scientific proof, indeed they date back to centuries when a belief in the mind and the soul as separate entities from the brain and the physical body was not challenged by emerging scientific understanding. We may now reject the idea of the ghost in the machine or the homunculus, but we still are very wedded to a view of the world which feels in tune with how we 'experience' our lives. Such belief systems may be termed 'folk psychology', but that does not alter their importance both for society and for the law. Findings from the Human Brain Project and the BRAIN Initiative or from subsequent investigations into brain processes may make belief in such folk psychology untenable and if that happens the implications not just for the law but for society may be enormous, but for the moment it is hard to see law abandoning its underlying belief in human autonomy, individual responsibility and free will.

3. MY BRAIN MADE ME DO IT

Belief in hard determinism would lead to the conclusion that all human acts are the consequence of prior events. However, one does not have to espouse this explanation of behaviour to see neuroscience as having the potential to challenge law's conception of responsibility. Discussion of the potential impact of neuroscience on the law often involve scenarios where a defence attorney^[51] calls an expert witness who shows by use of images of the defendant's brain that the defendant could not act otherwise and therefore should not be punished. In these scenarios the jury typically will find the images of the brain with areas highlighted in different colours to denote areas of brain activity or areas of brain atrophy or damage incredibly compelling. The sub text of such scenarios is often that undeserving defendants will "get off" and that unscrupulous lawyers and scientists will hoodwink jurors and the courts.

The idea of mental condition defences is not new, nor is receiving supporting medical evidence. The M'Naghten Rules,^[52] from 1843, still provide a defence in English law for individuals whose "defect of reason" results from a "disease of the mind". In the days before modern cognitive neuroscience, expert evidence would be presented to the court on the issue of whether or not a defendant suffered a defect of reason arising from a disease of the mind^[53] or suffered from an 'abnormality of mind (whether arising from a condition of arrested or retarded development of mind or any inherent causes or induced by disease or injury)'.^[54] This expert evidence might typically come from psychiatrists and medical practitioners. These experts would be likely to be drawing on observation of the accused, the accused's performance in tests and interviews and the accused's medical history.

The idea that individuals whose brains do not function properly should have a defence or a partial defence persists, as is seen in the new English law on diminished responsibility which refers to 'abnormality of mental functioning' arising from a 'recognised medical condition'.^[55]

Adding neuroscientific evidence such as functional or structural brain scan evidence to this mix does not transform the legal process. In an adversarial system, such as that in England and Wales or that applying in the United States, both prosecution and defence will have the opportunity to present neuroscientific expert evidence. In an inquisitorial system, such as those operating across most of continental Europe, the selection of the expert witness may be more critical as there will not necessarily be an alternative expert view presented. However, this is no different to other experts. Fingerprint evidence and DNA evidence have proved vital in helping to determine many criminal cases; yet they have not challenged the essence of the criminal trial. Similarly, brain scan evidence or other neuroscientific evidence relating to the mental functioning of the defendant may in some cases be highly significant in determining the outcome of the trial, but it will not fundamentally alter the criminal process.

3.1 IDENTIFYING GENUINE CASES

An example of a case in which brain scan evidence was critical is the case of Mohammed Sharif.^[56] Sharif was charged with conspiracy to defraud. Prior to trial it was argued that he was unfit to stand trial. The prosecution expert, a psychologist, concluded that it was 'a clear case of malingering and that there was no psychiatric or mental component'.^[57] The defence expert, similarly concluded that Sharif was not suffering from any serious mental disorder and was fit to plead. Unsurprisingly, given the views of the experts on both sides, Sharif was found fit to stand trial.^[58] At his trial the issue as to whether he was fit to plead was again argued, and again it was found that he was fit to plead. Sharif gave no evidence and was convicted and sentenced to three years' imprisonment. Leave to appeal was refused. In 2001 an application was made to the Criminal Cases Review Commission (CCRC) to consider his case. The CCRC's investigation was very detailed and took a long time, eventually leading to the case being referred to the Court of Appeal. The Court of Appeal concluded that Sharif had not been fit to stand trial and quashed his conviction. The reason for the volte face essentially turned on brain scan evidence. An MRI scan of Sharif's brain conducted shortly after his conviction showed a marked deterioration compared to a scan taken before he was convicted. A considerable number of experts assessed the evidence and concluded that there was clear evidence of progressive organic brain disease. The Court of Appeal concluded that Sharif had not been faking his disability at trial and that his conviction was unsafe.

The *Sharif* case illustrates an area where neuroscience may be particularly helpful to the courts and those administering justice more generally in determining whether mental condition defences are genuine or faked. Concerns exist that individuals can be taught how to defeat psychological tests in order to escape justice; whereas brain scan evidence, whilst clearly open to alternative interpretations does provide more robust, less easily faked, evidence. In England two high profile cases are particularly notorious. Ernest Saunders is often described as the man who recovered from Alzheimer's. Saunders was chief executive of Guinness plc and was involved in a share trading fraud connected to the take-over by Guinness of Distillers plc for which he was sentenced to five years' imprisonment. Saunders appealed and the sentence was halved because the judge concluded that Saunders was suffering from pre-senile dementia associated with Alzheimer's disease.^[59] Tests indicated that Saunders did not know how to use a door, wrongly named George Ford rather than George Bush as being the then President of the United States and was unable to recite three numbers backwards.^[60] Saunders was released early as his symptoms were apparently worsening.^[61] Following release the symptoms did not develop and Saunders was able to return to work as a highly paid business consultant and company executive. In 2000, following a long drawn out court process^[62] the former Chilean dictator General Augusto Pinochet, was released by the Home Secretary on the basis of medical evidence that he was not fit to stand trial.^[63] The decision was highly controversial - controversy which was exacerbated when Pinochet returned to Chile and promptly got out of his wheelchair at the airport to wave to his supporters and family.^[64] The two cases would not necessarily have been decided differently today. The Pinochet case was highly political and whilst the reason given by the Home Secretary was expressed in legal terms, unfitness to stand trial; the decision not to extradite to face trial for human rights abuses was arguably more to do with General Pinochet's support for the UK in the Falklands War and his strong links with the US government. Ernest Saunders' appeal, may have been based on seemingly fairly easy to defeat psychological tests, but it was supported by brain scan evidence.^[65] Critics of the use of brain scan evidence in the court room can argue that the Saunders' case raises questions as to the reliability of brain scan evidence; and the fact that individuals may give it too much weight. Jeremy Warner quotes a fellow journalist commenting at the appeal:

"Well there you are," whispered the man from the Sun. "Not even Ernest is capable of conning a brain scanner."^[66]

However, it is not so much a case of "conning a brain scanner". It is more a case of interpreting the evidence. Saunders' case took place in 1991; in the ensuing quarter of a century the ability of experts to interpret brain scan evidence has improved considerably and with the money being invested in the field it is reasonable to anticipate that it will continue to improve. Therefore, there is a strong possibility that neuroimaging evidence will provide robust evidence to assist in determinations as to whether someone is for example unfit to stand trial - particularly where as in Sharif's case there are a number of scans which can identify whether there has been deterioration over time.

3.2 RESHAPING THE LAW

An American case raises a number of interesting questions for the law. An individual, who has hitherto been a law abiding pillar of society, starts to behave differently. He accesses internet pornography, he frequents prostitutes and then he makes sexual advances to his pre-pubescent step daughter. He is charged and convicted. The court gives him the option to attend an inpatient treatment programme or to go to prison. He chooses the rehabilitation programme. However, once on the course he starts making sexual advances towards fellow patients and nursing staff. He is removed from the programme and the night before he is due back in court he complains of intense headaches. A brain scan reveals a very large tumour pressing into the right orbito frontal

part of the brain. Alongside his increasingly unrestrained sexual behaviour, other aspects of his behaviour are also changing. He is walking with an unsteady gait and he is urinating on himself. When tested he is unable to complete relatively simple tasks such as drawing a clock face. The tumour is removed and he ceases to make sexual advances to those around him, his walking returns to normal, he stops urinating on himself and he is once again able to complete simple tests such as drawing a clock face. Seven months later he is able to return to live with his partner and his step daughter. Life appears to have returned to normal. Then the impulses to look at internet pornography return. The tumour had regrown. The tumour was removed. The impulses disappeared.

Was his undesired behaviour 'caused' by the brain tumour? Was he 'responsible' for his acts? Was there a point when he could control his actions and a later point when he could not? Does the fact that initially he concealed his behaviour from others evidence that he could control his behaviour or only evidence that he could conceal it? Do any of these questions matter to the law? Should they matter to the law?

Looked at from an English law perspective the sexual advances made towards his step daughter would appear^[67] to amount to sexual assault of a person under 13^[68] or sexual activity with a child.^[69] Both offences carry a maximum sentence under English law of 14 years' imprisonment. Under English law the only possible defence would be insanity. A first point to note is that, if the defence were to succeed, labelling someone with a brain tumour insane is neither medically nor in terms of societal understanding appropriate. However, in reality the defence is unlikely to be available in this case. He may have a "defect of reason" arising from a "disease of the mind", but he probably does not satisfy the rest of the test. To satisfy the test he must additionally persuade the court that he either did "not know the nature and quality of his act" or did not know that his conduct is legally wrong. On the facts neither test appears to be satisfied. Therefore, notwithstanding his brain tumour, he is likely to be found guilty. Without the brain scan evidence this is just a case about an individual who appears to have acted out of character for a short period in his life. With the brain scan evidence coupled with the neuroscientific understanding that the area of the brain impacted by the brain tumour is the primary area for impulse control we have a much better understanding of how the out of character behaviour arose. If the brain tumour is now removed is the offender no longer a threat to society? Should he be punished, if he could not control his impulses? If he no longer has those impulses (or he can now control those impulses) should he be free to resume his position in society free from a criminal record and without his name appearing on the sex offenders register. Neuroscience does not provide an answer to these questions, but it does help understand the offending behaviour and the assessment of future risk.

It could also help shape reform of the law. This is not to say that law reform would not occur but for the insights provided by neuroscience. The Law Commission for England and Wales have already recognised the need to reform the law on insanity and automatism^[70] - the difference is that through our increasing knowledge of the workings of the human brain that reform can be better informed. The current proposal to replace the old defence of insanity with a new defence of not criminally responsible by reason of a recognised medical condition is an example of how the law can benefit from greater scientific understanding. If the proposal was to be implemented, then the individual in Burns and Swerdlow's case study would fall within the new proposed defence if he 'wholly lacked capacity' to control his physical acts.^[71]

3.3 DEVELOPMENTAL (IM)MATURITY

Under English law an individual is criminally responsible from the age of ten onwards. Other European countries have higher ages of criminal responsibility.^[72] English law's approach of imposing criminal responsibility so young is at variants with the growing understanding arising through neuroscience. As the Royal Society note:

"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. 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."^[73]

When considering criminal behaviour the prefrontal cortex, with its significance in terms of judgement, decision-making and impulse control, is clearly crucial and yet this is described as the slowest to mature. Holding teenagers and pre-teens criminally responsible as if they were adults when it is to be expected that they will not have developed their ability to think through decisions fully or to control their emotions is unjust. A graduated approach which assesses each individual according to their level of responsibility would be a possible route.^[74] Under English law there used to be a rebuttable presumption of *doli incapax* for children aged under 14. This had the effect that those aged from 10 to 13 were presumed not to be criminally responsible unless the prosecution could show that at the time of committing the offence the child knew the difference between right and wrong. However, in 1998 Parliament abolished the presumption.^[75] In *R v JT*^[76] the House of Lords explained the change on the basis that compulsory schooling had made the old common law presumption redundant.^[77] From the court report it appears that in arriving at their decision the court gave no consideration to the countervailing neuroscientific evidence. It may be true that school children are taught the difference between right and wrong, but this does not address the issue that when teenagers and pre-teens are in emotionally charged situations they may behave in ways which are very different to how they would respond later in life as mature adults. Labelling such children and young adults as criminal may reflect what they have done, but may not reflect their degree of responsibility for their acts and may severely damage their future life prospects.

The USA has been more receptive to neuroscience based developmental maturity arguments. Farahany's research found 84 reported cases between 2005 and 2012 in which general developing brain theory arguments^[78] were used by defendants and in 21% of these cases the appellant was successful.^[79] The period

also saw three important Supreme Court decisions all of which drew in part on neuroscientific understanding of juvenile brain development. In *Roper v Simmons*^[80] it was held to be unconstitutional to execute anyone convicted of a crime which was committed before the age of 18. In *Graham v Florida*^[81] it was declared unconstitutional to impose life without possibility of parole for a non-homicidal juvenile offence and in *Miller v Alabama*^[82] it was decided that it was unconstitutional to impose mandatory life imprisonment without possibility of parole for juvenile offences.

Whether English law will remain out of line with scientific understanding in this area is unclear. The Law Commission proposed a partial defence to murder for young offenders.^[83] However, this proposal was not implemented. Lord Philips, the then senior Law Lord, criticised this omission:

"It is surely offensive to justice that a child whose brain has not yet developed to the extent necessary to provide the self-control that is found in an adult should be unable to pray this fact in aid, at least as a partial defence" ^[84]

However, the Law Commission have recently returned to this theme in their examination of possible reform of the criminal law defences of insanity and automatism. In looking at the issue they examined some of the neuroscientific evidence on brain development^[85] and concluded that there was a need to examine whether law reform was required in this area.

3.4 PERSONALITY CHANGE

The orbito frontal tumour case is not the only example of personality change. The classic example of a serious head injury leading to changed behaviour is that of Phineas Gage. In 1848 Gage was injured in a terrible accident when working on the rail road. Amazingly Gage survived despite having had a large iron rod driven through his skull by an explosion. The rod went through and destroyed most of the left frontal lobe of his brain. Whilst there has subsequently been dispute as to the extent of the change to Gage's personality following the accident; there is agreement that his personality changed. His case helped support those nineteenth century scientists who believed that certain parts of the brain had specific functions. This work has progressed enormously so that now through functional brain imaging it is possible to identify those parts of the brain that carry out different functions and therefore better understand the likely effect of injury or atrophy in those areas.

An interesting English case on this issue is *Meah v McReamer*.^[86] Christopher Meah suffered a serious head injury when the car in which he was a passenger was involved in a head on collision. Meah suffered damage to the pre-frontal cortex. Those who knew him gave evidence that his character changed following the accident. He became more callous and sexually less empathetic. Three years after the car accident he committed a number of very serious offences and was convicted and sentenced to life imprisonment for sexual assault, rape and wounding. Meah sued the driver of the car for damages, arguing that but for the driver's negligence he would not have committed the offences and so would not be in prison for life. Expert witnesses all agreed that the injuries he sustained could and probably did lead to personality change. They were divided as to whether one could conclude that the head injury led to the commission of the crimes. The trial judge found that the evidence of the experts arguing that had it not been for the head injury he would not have committed the offences most convincing and awarded Meah damages for the time he would spend in jail.^[87] Subsequently, the House of Lords held in the case of *Kerrie Gray*^[88] that, applying the principle that one should not be allowed to profit from one's wrongdoing,^[89] damages should not be awarded in cases where an individual is seeking compensation resulting from his own criminal behaviour.

4. PERSONAL INJURY

The cases of Christopher Meah and Kerrie Gray were unusual compensation claims. However, notwithstanding the limitations imposed by the Gray decision, compensation for personality change is now well established in English personal injury cases.^[90] The Judicial College Guidelines^[91] help the courts determine the level of damages appropriate in personal injury cases. In the section on brain damage, guidance as to the amount of compensation to be awarded is linked to the extent of brain damage.^[92] As would be expected, brain scan evidence is often used in such head injury cases. The ability to evidence brain injury with neuro-images can be very useful in not just proving the genuineness (or otherwise) of the injury, but also in assessing the likely prognosis for the injured party. Previously, the courts would have to rely on medical prognoses based on the victim's performance in tests of brain function and the apparent severity of the injury. With neuroimaging evidence the extent of brain injury can be better assessed and as a result the likelihood of and the likely extent of recovery can also be predicted more accurately.

Another very important area where neuroscience can assist the law is in determining the cause of injuries. Cases of alleged non-accidental head injuries (NAHI) in infants have proved particularly problematic for legal systems. It is vital to differentiate accurately between on the one hand tragic deaths and injuries arising from natural causes and on the other hand cases of murder, manslaughter or assault. In such cases the victim may either be dead or too young to give evidence. The only witness(es) may well be the possible perpetrator(s). To elicit the truth, it is likely that medical evidence will be vital. Following a finding that the conviction of Angela Cannings for the murder of two of her children was unsafe,^[93] the authorities took the unusual step of writing to certain individuals who had been convicted suggesting that they might like to consider an appeal. In one such case the Court of Appeal heard an appeal relating to four cases of alleged NAHI.^[94] The appeals turned on the expert medical evidence, much of it neuroscientific. Ten expert witnesses were called by the appellants and 11 by the Crown. Two of the appellants had their convictions for murder quashed. In one case the murder conviction was reduced to manslaughter. One verdict was upheld. In all the cases the evidence of the nature of the brain injuries and whether they were the product of the child being deliberately shaken was vital. The judgment is unusual in that in addition to the normal judicial reasoning, the judgment also contains two appendices: one covering medical terminology and one containing diagrams of the brain.

4.1 PAIN

One area of personal injury claims which is particularly problematic is compensation for pain and suffering. Few would argue that a person who is injured and suffers pain and suffering as a result of another's deliberate or negligent act should be compensated. The problem for the law is that pain is essentially a subjective experience and the person experiencing the pain has a financial interest in persuading the court that the pain is severe. This fact may both tempt claimants to exaggerate the pain that they suffer and may lead to courts and insurers being unduly cynical and dismissive of claims that are made. Assumptions may be made based on the type of injury as to the likely level of pain, but these may not be accurate. Ideally the courts should be able to compensate the victim for the actual pain suffered rather than on the basis of unverifiable witness testimony or generalised assumptions that may not be applicable to the victim in question. Neuroimaging does not yet provide a measure which can conclusively demonstrate whether an individual is suffering chronic pain or the extent of that pain, but the science is advancing and in the reasonably near future this information may be available to the courts and insurers.^[95] Given the huge sums involved this will be a very important development. In the United Kingdom musculoskeletal conditions cost the NHS over £5 billion annually^[96] and lead to over 30.6 million working days being lost.^[97] The total annual indirect cost of back pain has been estimated at £10 billion a year.^[98] Better identification of those genuinely in pain will not eliminate these costs, but it will allow money to be much better targeted. It could also help provide objective evidence of the effectiveness or otherwise of treatments aimed at alleviating pain. Additionally, it could help differentiate genuine claimants from those who are trying to cheat the system; particularly in areas such as alleged whiplash injuries where physical evidence of injury is notoriously difficult to prove. This potential to differentiate the genuine from the spurious could be very valuable in relation to some disability benefits where claimants may struggle to evidence the existence or extent of their physical disability, but may genuinely be in severe pain and hence unable to work.

4.2 SPORT

One of the largest personal injury claims has been that brought by American football players against the National Football League (NFL) after it allegedly concealed knowledge of the risks of concussion.^[99] The \$1 billion plan is to compensate players who have suffered head injuries. The deal does not involve any admission of wrongdoing on the part of the NFL. The case followed a number of high profile incidents, some involved the early retirement of leading players,^[100] others more disturbingly involved suicides by former players.^[101] Without neuroimaging the extent of the damage to players' brains would not have been apparent and the NFL might well have persisted with its approach of denying the serious adverse health effects related to repeat concussion.^[102] Neuroimaging has not only helped demonstrate the existence of brain damage in both professional American footballers and those playing at lower levels including those still at school, but it has also enabled chronic traumatic encephalopathy (CTE) to be identified in the brains of American footballers. Currently these tests are only definitive when conducted after death, but shockingly over 95% of former American footballers' brains that have been posthumously examined have revealed evidence of CTE. Evidence from neuroimaging studies have influenced changes in the rules of American football^[103] and amateur boxing^[104] but other sports including rugby are under pressure to do more.^[105] As neuroimaging becomes more advanced, for example once CTE can be confidently identified in living patients, it is likely that pressure for change to sporting rules will become greater and the potential for civil actions and possibly even criminal actions against sports authorities will increase.

5 LIES AND MEMORY

Without knowing the facts, it is impossible to do justice. However, in order to discover the facts courts are typically dependent in very large part on witness' testimony. Jurors and others who have to determine the facts often face conflicting accounts of events given by different witnesses. Their role is to assess the credibility and truthfulness of the witnesses. There are many factors which may impact on a juror's or a judge's approach to this task. The plausibility of the evidence, its coherence, whether it is supported by other evidence, whether it fits the narrative given by other witnesses, the demeanour of the witness: all these factors and more are likely to influence the juror or judge in trying to sift through the evidence in the quest for the truth. In such a situation would it not be helpful to the juror or judge to know if the witness was telling the truth?

Laboratory tests suggest that humans are not very good at discerning deception.^[106] Typically, in these tests an individual is told to lie in response to a particular question or questions and the individuals being tested are asked to identify when the actor is lying. Many of these tests take place in universities and make use of the most readily available participants: university students both as actors and as those being tested. University students are likely to be better educated and younger than the average juror. Factors which may be relevant in determining a person's ability to discern deception. Additionally, the setting is very different from the courtroom setting. Giving evidence in court for most people will be a very nerve wracking experience. Playing a role in a laboratory test is unlikely to reflect this. A witness in a courtroom setting who is trying to deceive a jury is in a very different position from an actor in a university experiment who is trying to slip untruths past a group of university students. However, whilst laboratory tests may not be a very good method of mirroring the courtroom setting, they do raise serious concerns about our ability to discern deception - a skill which is central to the pursuit of justice. The possibility exists that groups of individuals working together to separate the true from the false are more accurate than individuals working alone. However, it is unclear whether the jury set up where jurors hear all the evidence and then discuss is closer to the group model or a multiple individual model. Jury systems are not universal; where used they are often confined to criminal trials and often only for the most serious criminal offences. Whether judges are better at discerning deception than lay jurors is unclear. Their experience in assessing witnesses may make them more skilled; alternatively, it may lead them to become cynical and case-hardened.

Many companies and scientists are keen to bring such technology into the courtroom.^[107] This is not new. The *Frye* case,^[108] back in 1923, was an appeal against the decision of the trial court to exclude polygraph evidence supporting the contention that the defendant was telling the truth. In that case the test was described as "a systolic blood pressure deception test".^[109] The exclusion of the evidence was not because the courts would not countenance the introduction of such evidence, but because the technology was deemed not yet sufficiently robust:

Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.^[110]

Over the years many lie detection systems have been devised; more recently attention has focussed on neuroimaging as a means of determining whether an individual is lying. Functional magnetic resonance imaging (fMRI) shows the use of oxygen in different parts of the brain. It is claimed that the Blood Oxygen Level Dependent (BOLD) hemodynamic response has the potential to identify lying at source (i.e. inside the brain) and is therefore arguably more reliable than polygraph technologies which identify signs of stress such as galvanic skin responses. Small scale comparative tests have suggested that fMRI performs better at identifying deception than polygraphs^[111] and that combined the two approaches are even better at identifying deception and suggestions have been made that fMRI lie detection should be admitted in certain circumstances.^[112]

Linked to, but separate from, lie detection is memory detection. Claims have been made that neuroimaging offers opportunities to identify whether an individual has memories of for example a particular place or a particular object. Brain activity associated with recognition and recovery of memories is thought to differ from brain activity when something is seen or heard for the first time. The initial response is viewed as being subconscious and therefore harder or impossible to fake, making proponents of the technology much more confident as to its accuracy as a "guilty knowledge test".^[113] Some argue that such technologies are already ready to be admitted into the courtroom^[114] but so far, in most jurisdictions, the courts have been reluctant to admit neurotechnologies into the courtroom to 'prove' whether a witness is telling the truth.

This is not to say that all jurisdictions have been so reticent. Possibly the greatest international interest in memory detection in the courtroom has arisen through its use in India.^[115] In India the Brain Electrical Oscillation Signatures (BEOS) test has been used to test whether witnesses including defendants have memories of significant facts associated with the case in which they are involved. Probably its most (in)famous use was in 2008 when Aditi Sharma was convicted of murdering her fiancée, in part on the basis of the interpretation of her brain responses when shown images related to her alleged crime. Her conviction was subsequently overturned on appeal, though the principle that such evidence can be admissible provided the right safeguards are in place is accepted by the Indian Supreme Court.^[116]

Much focus on the potential introduction of lie detection and memory detection into the courtroom is on human rights. The idea of compelling an accused to undergo lie detector or memory detection tests particularly if that test is going to be based on neuroimaging of the brain is seen to raise fundamental constitutional issues particularly around the privilege against self-incrimination contained in the Fifth Amendment.^[117] For European audiences, Article 8 of the European Convention for the Protection of Human Rights and Fundamental Freedoms is possibly most relevant with its qualified protection of privacy, though Article 3 with its protection from inhuman and degrading treatment may also be engaged. If the technologies become more reliable then the pressure to include such evidence in court is likely to increase. In the short term, State pressure may be to utilise such technology both pre and post-trial, rather than at trial. England and Wales already use polygraphs, in the form of galvanic skin response testing, to assess whether sexual offenders released on licence are complying with release conditions.^[118] Evidence from the polygraph tests is explicitly excluded from court,^[119] but refusals to comply with the testing regime or disclosures given whilst tested are likely to lead to the individual's release on licence being curtailed and the offender being returned to prison. If polygraphs are used and if neuroimaging is more reliable, then as the costs of neuroimaging come down, it is likely that the pressure to adopt this approach will become greater. As noted in Ed Johnson's article^[120] the English police have also trialled the use of polygraph testing pre-charge. It is easy to see the temptation for law enforcement authorities to seek to use an arguably better technology, based on neuroimaging, as part of their process of identifying and eliminating suspects in the same way as they might currently use finger print or DNA evidence. Suspects and others thought to have been in the vicinity of a crime can currently be asked to agree to be finger printed or to give DNA evidence. Refusal to voluntarily comply with such a request may lead to an individual being viewed as being a suspect. States could go a stage further and require that individuals undergo brain scanning to ascertain whether they are lying or whether their memories contain apparently guilty knowledge. This has already been done in relation to fingerprints and DNA evidence.^[121] The question whether brain responses are fundamentally different from evidence such as fingerprints and DNA is debatable. Hank Greely has provided a strong argument that it is:

"Effective mind-reading threatens to invade a last inviolate area of 'self'. Like removing the membrane from a living cell, removing our ability to withhold our mind's workings may threaten to eliminate, at least for some mental states, emotions or thoughts the difference between 'self' and 'other'".^[122]

Compelling individuals to give up their thoughts and memories in such a manner may seem the greatest invasion of privacy imaginable, but in the pursuit of justice should the State be allowed to take such a step? So long as the technology remains insufficiently robust this question can be side stepped, but there is likely to come a time when the question must be addressed. The question may well be first posed in relation to the privacy rights of terrorists and suspected terrorists. Using fMRI or EEG may seem a much less oppressive approach to eliciting the truth than water boarding or other forms of torture. It may also be more effective at eliciting accurate information. However, concluding that something is more acceptable than torture, does not make it acceptable.^[123] Earlier in the article it was noted that 50% of initial US government funding for the BRAIN Initiative was coming from DARPA. DARPA's interest in covert remote neural monitoring and imaging^[124] probably explains part of the agency's reasons for supporting the project. Currently, individuals are watched at, for example, airports to see if they are acting suspiciously - from a security perspective how much better if not only their actions and demeanour, but their thoughts could be monitored? Individuals being questioned, particularly trained individuals, may take counter measures to attempt to conceal the fact that they are lying or concealing the truth when questioned. This may fool a human questioner or even someone reading polygraph, fMRI or EEG results, but if the attempt to extract information was conducted surreptitiously the individual would not know to initiate counter measures. However, as a society we may not object to being observed to see if we are behaving suspiciously whilst we are in a public place; particularly if there is good reason for security

measures being in place. In the UK, for example, Closed Circuit Television in public areas has been widely accepted by the public as a valuable crime prevention and crime detection tool. Airport security measures including body scanners are accepted around the world by those seeking to fly. Is covert mind reading just a logical progression or a completely different ball game? Would societies embrace it as an important security enhancing measure, reject it as a wholly unacceptable invasion of privacy or pragmatically want to assess its use on a case by case basis?

The party seeking to use such technology might not be the State. Should an employer be able to insist that an employee should undergo a lie detector test? We accept that an employer can question an employee when for example money goes missing? If the interpretation of the answers is more accurate if some form of lie detection technology is involved, then should its incorporation into the questioning process be welcomed? What about gathering information about the employee's attitudes? Is it appropriate for an employer to try to ascertain whether an individual is for example racist or sexually attracted to children? Would it depend on the employee's role? Psychological testing can already help inform such assessments, but fears exist that employees may give the answers that they think are desired rather than reveal their genuine beliefs. Neuroimaging may be more difficult to fool, but is it too great an invasion of privacy? At some point in the not too distant future courts may be called upon to assess the nature and extent of measures that employers can introduce to assess the suitability of their employees and prospective employees. It need not be an employer, a wide range of parties may wish to embrace this technology as it becomes more accurate and cheaper and easier to use. Adoption agencies could use it to decide whether prospective adopters would be suitable, individuals may want to find out if a prospective spouse or partner is telling the truth, electors may wish to know more about the guilty knowledge and/or veracity of their politicians.

This section has focussed on neuroimaging being used to detect memories and lies from those who are trying to conceal them. However, there are also those who will seek to use neuroimaging to 'prove' the truth of their testimony. In *Semrau* [125] it was the accused who wished to demonstrate the veracity of his testimony by seeking to introduce fMRI evidence to support his contention that he was not guilty of fraud. Such cases do not raise the privacy and privilege against self-incrimination arguments that are raised in cases where it is the other side who wish to compel a witness to undergo neuroimaging to test whether they are lying or concealing guilty knowledge. In *Semrau*, Judge Tu Tham excluded the evidence as not satisfying the *Daubert* test [126] and not satisfying rule 403 of the Federal Rules of Evidence. [127] In a detailed assessment of the current state of scientific knowledge the judge focussed on how the science had not yet been adequately tested in real life situations. However, he did not rule out that at some stage in the future such evidence could be admissible. Evidence given simply to bolster the credibility of a witness is excluded in many jurisdictions [128] but if that evidence was compelling there seems little logic as to why a court attempting to achieve justice would wish to exclude that evidence. The argument that it would be usurping the role of the jury [129] in determining whether witnesses were telling the truth seems weak if the aim of trials is to achieve justice and if, as appears from the research, humans are poor at identifying lies.

Clearly more research is needed to determine whether in the real world lie detection and memory detection works or can be made to work. To be robust it will be helpful if it can differentiate between honestly held/recounted inaccurate memories and honestly held/recounted accurate memories. However, even if it cannot, the technology could at some point in the future afford a useful supplement to human abilities to assess the veracity and accuracy of witness testimony. Yet examination of this technology is not just something for the future; it is already used in some jurisdictions and outside the courtroom in several others.

6 NEURO-ENHANCEMENT

Neuro-enhancement which arises from, for example, good diet, healthy sleep habits and education is largely uncontroversial [130]. Similarly, the benefits deriving from the elimination or reduction of factors such as pollution which damage neurocognitive abilities are equally likely to be viewed as ethically unproblematic. Equally, assisting those with impaired cognitive abilities to reach or get closer to the societal norm is unlikely to be seen as raising significant ethical dilemmas, particularly where such support has no, or very limited, adverse side effects and where those helped consent to the assistance.

However, where neuro-enhancement aims to assist those with normal cognitive abilities to perform better than the norm this starts to raise questions of unfair advantage - particularly if the opportunity to benefit is not open to all within society. A number of drugs are claimed to have benefits which could assist an individual to perform better. Claims are made, for example, that Modafinil increases attention, enhances wakefulness, improves planning, improves decision making, improves motivation and improves memory. Assuming that these claims are genuine is it fair that individuals should be able to benefit in this way? In sport decisions have been made to ban performance enhancing drugs on the basis that they give those who take them an unfair advantage. Should the same approach apply to other areas of life? These questions may appear primarily ethical rather than legal issues, but if we move to a conclusion that some behaviours are unethical the next questions logically will be to ask if they should be illegal. Assuming that claims that Methylphenidate increases concentration, improves memory consolidation and improves problem solving should students be allowed to take it when preparing for exams? Currently some drugs are available only on prescription and are targeted at assisting those with particular problems, but where these drugs are generally beneficial there is an argument that they should be more widely available. At present, this argument can generally be avoided by pointing to actual or potential side effects that can be employed to warrant banning such drugs for non-therapeutic use. However, as we gain more understanding as to how the brain works and as more money is invested into neuropharmacology it becomes more likely that drugs will be developed which have clear neurocognitive benefits for those with normal or heightened cognitive abilities and either no or minimal side effects.

However, it is not just drugs which potentially provide such benefits. Transcranial Direct Current Stimulation (tDCS) is claimed to enhance mathematical and language ability, improve memory, attention span, concentration and coordination. The devices are affordable and easily available [131]. As with current neuropharmacological drugs there are doubts as to whether tDCS actually works on healthy adults [132] but this does not mean that devices which do have significant benefits will not be developed. Assuming such drugs and

devices do not raise health and safety issues one question is whether they provide those who use them with an unfair advantage and if so, whether they should be prevented from gaining this advantage.

A second question is whether employers should be permitted to ask or even to demand that their employees take them. Half the initial public funding of President Obama's BRAIN Initiative is from the military. If DARPA or its equivalent in other countries was to develop a drug which increases attention, enhances wakefulness, improves planning, improves decision making, improves motivation and improves memory^[133] or indeed does any one of the above without any significant adverse impact on other areas of performance would it not want its military personnel to take the drug? In an environment where individuals are used to following orders getting people to take the drug might not be problematic, but in another profession such a request / demand from an employer might meet resistance. Suppose at some point in the future that a drug is shown, for example, to enhance hand eye coordination and suppose that all available evidence indicated that there were no adverse side effects should, for example, a hospital trust be able to insist that the surgeons that it employs used the drug? Could a point be reached where the hospital trust was negligent if it did not insist?

Another area where neuro-pharmacological enhancement enters muddy ethical waters is where it aims to make an individual morally better. Moral enhancement through 'good' parenting, the example of role models or through education will generally be seen as positive. Moral enhancement through religious teaching is for many a central element in developing a moral compass; though some would see it as superstitious mumbo-jumbo. However, what if a drug would make the person taking it, for example, more empathetic would this be acceptable? Is being "good" about the struggle to be good or is it about the result. Should society admire the person who is tempted to be "bad" and chooses to be "good" more or less than the person who is "good" because that is all that they want to be. Are these simply ethical questions which need not concern the law or are they matters about which legislators and the courts should develop approaches? Is there a material difference between drugs which will reduce aggressive behaviour and drugs which will promote altruistic behaviour? We are already at a point where drug treatment to alter behaviour in Europe and the United States is widespread and is often focussed on the young.^[134] These interventions can be viewed as medical where the 'problematic' behaviour is labelled a disorder, but definitions of disorders vary over time and between cultures. In England, homosexuality was viewed as a disorder and those convicted of homosexual offences could be offered the option of hormonal treatment, in effect chemical castration, as an alternative to prison. Now in England, not only is homosexual activity no longer illegal, but discrimination on grounds of homosexuality is illegal and gay marriage and adoption by gay couples is not only allowed, but celebrated.

7 BRAIN COMPUTER INTERFACES

Technological advances have enabled those with disabilities to improve their quality of life and gain greater freedom for example through cochlear and retinal implants. Robotic arms controlled by thoughts and nerve impulses provide greater independence for a growing number of disabled individuals and suits are being developed which will respond to brain impulses to enable tetraplegic individuals to walk again. In general terms these developments appear very positive, but they do raise some legal questions. If someone with a robotic arm strikes another person because they fail to control the arm effectively - should the blow be viewed by the law as an assault? If someone deliberately damages a neuroprosthetic should it be viewed as criminal damage or as assault? Once upon a time the idea of bionic humans with enhanced abilities might have been the stuff of TV series such as *The Six Million Dollar Man* or films such as *Robocop* but increasingly science is catching up with fiction. Should there be any legal limits on the abilities which humans can be given? If so, how should these limits be set?

Developments in neuroscience have also enabled those for example coping with locked in syndrome to communicate with the world. The individual with locked in syndrome who is perhaps best known to English audiences was Tony Nicklinson. His impassioned appeals to be allowed to die with dignity^[135] attracted much support from the public at large, but failed to persuade the courts^[136] and Parliament.^[137] The current situation is that English law is out of line with the apparent views of the majority of the population. Interestingly, the President of the Supreme Court, Lord Neuberger, was of the view that if it were possible to provide for Nicklinson and others in his situation with the technological means to commit suicide, then this would not amount to assisting suicide, but would be a means of supporting personal autonomy.^[138] This illustrates how, for at least the most senior of the Supreme Court judges, technology could transform the legal situation.

Technology also affords an opportunity to communicate with some of those with even more difficulties in expressing their wishes, concerns and feelings. The work of Adrian Owen, Stephen Laureys and others has enabled some patients diagnosed as being in Vegetative States (VS) and Minimally Conscious States (MCS) to answer questions. This provides the opportunity to learn more about the experiences and wishes of such individuals. Using fMRI individuals who cannot otherwise communicate with the outside world can be asked to think about for example walking around a house for "yes" and playing tennis for "no". The different thoughts should involve BOLD readings in different and distinct parts of the brain depending on the activity on which the individual is concentrating. By testing responses in relation to questions for which the answer is known^[139] and repeating questions to ensure consistency of response those seeking responses can then progress to issues about which those posing the questions are less certain; such as whether the individual is in pain. Whilst the two option structure of the questions is very limited; it could help for example in achieving the best treatment of such individuals in hospital. The limited dialogue opportunities afforded by the current technology does not provide the means by which a patient could give informed consent to a proposed treatment as the patient cannot raise questions or alternative treatment options. However, arguably the existing technology would allow the patient to express preferences between two options. Contentiously, this could include the ability to express a preference to live or die.^[140]

8 CONCLUSION

If hard determinism becomes not only the accepted discourse of science, and but also accepted by politicians, policy makers, judges and society at large then it will challenge the foundations of not just law, but social

interaction generally. We believe that we have choice, if we become convinced that such a belief is untenable then our current folk psychology will have to evolve. However, we are wedded to our belief that we have choice and therefore the extreme option that "for the law, neuroscience changes ... everything" is unlikely to be imminent. The alternative option presented by Greene and Cohen that "for the law, neuroscience changes nothing" is equally untrue.

Neuroscience has already affected court decisions and will continue to do so. Neuroimaging evidence can be the difference between life and death for some convicted of capital offences in the United States. In courts around the world it is being introduced to provide evidence as to the cause and extent of injuries. Neuroscientific evidence is being introduced to provide evidence of the mental state of defendants. It cannot provide evidence as to what an accused was thinking or intending at the time that the offence was committed; but it can provide evidence to support or counter arguments about for example abnormality of mental functioning or fitness to plead. Neuroscientific evidence is not alone in being able to do this. Psychiatrists, psychologists and other medical practitioners have given evidence in the courtroom on these matters for many years. However, neuroscience does provide new insights. The evidence from, for example neuroimaging, still needs to be interpreted by experts, but as understanding of the workings of the brain advance so the quality of this interpretation will improve and the importance of this evidence will increase.

The increased understanding of cognitive processes afforded by neuroscience may also lead to reform of the law. Parents have known since the dawn of time that decision making processes in children and young adults develop over time. Educationalists, psychologists and others have added to this knowledge. Neuroimaging is now providing an extra dimension to this understanding. This will not necessarily lead to legal change, but it adds to the pressure for law reform in countries such as England and Wales which have very low ages of criminal responsibility.

As noted, neuroscience has already had a very significant impact in providing better evidence in personal injury cases. For the moment neuroscience cannot determine the extent of chronic pain being suffered by personal injury claimants, but this may change. If it does change this will be a very major contribution to the legal process - allowing compensation to be much better targeted. Better understanding of head injuries may lead to changes in health and safety approaches in sport and in life more generally. Failure to respond to this greater understanding may lead to compensation claims as has already been seen in American football.

The impact of neuroscience on the law in areas such as lie detection, memory detection, neuro enhancement and brain computer interfaces is perhaps most difficult to predict. Lie detection or memory detection which is accurate in real life settings; would potentially revolutionise the court process and life more generally - but would societies be prepared to embrace the technology? Allowing others to read your thoughts and access your memories is a very clear invasion of privacy. Do the benefits outweigh the costs? This may become a major issue in the future. For the moment, it remains science fiction; but it will not necessarily remain so.

Neuro enhancement and brain computer interfaces designed to work therapeutically to bring individuals up to the norm may seem largely unproblematic so long as they work and do not have serious side effects. However, advances which enable individuals to be better than the norm raise different ethical and possibly legal questions - around unfair competition and what it is to be human. As the technologies advance these questions will have to be considered by legislators, the courts and society more generally.

The graph from the MacArthur Foundation, reproduced at the start of this article, illustrates the way in which scholarly discussion of these areas has been expanding over recent years. It is unlikely that this trend will alter. Understandings arising from cognitive neuroscience have the potential to transform not just the law, but society. Academic lawyers need to keep abreast of the scientific developments so that they can play a part in shaping the future.

[1] Head of Open University Law School, email: paul.catley@open.ac.uk

[2] Joshua Greene and Jonathan Cohen 2004 'For the law, neuroscience changes nothing and everything', *Philosophical Transactions of the Royal Society* B359, 1775

[3] The graph is available at: <http://www.lawneuro.org/bibliography/bibliograph2015.pdf> accessed 4/4/2016

[4] The Human Brain Project Report to the European Commission 2012 available at: https://www.humanbrainproject.eu/documents/10180/17648/TheHBPRReport_LR.pdf accessed 20/2/2016

[5] BRAIN in this context stands for Brain Research through Advancing Innovative Neurotechnologies

[6] The \$100 million of State money for 2014 was identified as coming from the Defence Advanced Research Projects Agency (DARPA) (\$50 million), the National Institutes of Health (NIH) (c. \$40 million) and the National Science Foundation (NSF) (c. \$20 million). The private funding was identified as being pledged by the Allen Institute for Brain Science (\$60 million p.a. for 10 years), the Howard Hughes Medical Institute (\$30 million p.a. for 10 years), the Kavli Foundation (\$4 million p.a. for 10 years) and the Salk Institute for Biological Studies (\$28 million). Source: Office of the Press Secretary, The White House 2nd April 2013, FACT SHEET; The Brain Initiative available at: <https://www.whitehouse.gov/the-press-office/2013/04/02/fact-sheet-brain-initiative> (accessed 20/2/2016)

[7] Presidential proclamation 6158 available at: <http://www.loc.gov/loc/brain/proclaim.html> (accessed 20/2/2016). The President's proclamation followed a resolution by Congress (House Joint

Resolution 174) the 1990s be declared the Decade of the Brain.

[8] Ibid

[9] The Overview of the Human Brain Project states: 'Understanding the human brain is one of the greatest challenges facing 21st century science. If we can rise to the challenge, we can gain profound insights into what makes us human, develop new treatments for brain disease and build revolutionary new computing technologies.' Available at: <https://www.humanbrainproject.eu/2016-overview> (accessed 01/07/2016). Similarly, the aims of the BRAIN Initiative focuses on treatments for brain diseases and on how it 'will accelerate the development and application of new technologies that will enable researchers to produce dynamic pictures of the brain that show how individual brain cells and complex neural circuits interact at the speed of thought. These technologies will open new doors to explore how the brain records, processes, uses, stores, and retrieves vast quantities of information, and shed light on the complex links between brain function and behavior.' Office of the Press Secretary, The White House 2nd April 2013, FACT SHEET; The Brain Initiative available at: <https://www.whitehouse.gov/the-press-office/2013/04/02/fact-sheet-brain-initiative> (accessed 20/2/2016)

[10] See for example *Totham v. Kings College Hospital NHS Foundation Trust* [2015] EWHC 97 (QB)

[11] See for example *R v Henderson*; *R v Butler*; *R v Oyediran* [2010] EWCA Crim 1269

[12] For example the maximum sentence for intentionally inflicting actual bodily harm under English law is five years imprisonment, whereas the maximum sentence for intentionally inflicting grievous bodily harm is life imprisonment.

[13] Owen D Jones. and Francis X. Schen, *Law and Neuroscience in the United States*, in International Neurolaw A Comparative Analysis, (Tade Matthias Spranger ed. 2011), 349

[14] In *Detrich v Ryan* 619 F.3d 1038 (9th Cir.2010) a defendant convicted of murder successfully argued that his trial counsel's failure to introduce evidence of his brain damage and neuropsychological deficits amounted to 'ineffective assistance'

[15] Nita A. Farahany, 'Neuroscience and behavioural genetics in US criminal law: an empirical analysis', *J Law Biosci* (November 2015) 2 (3): 485-509 first published online January 14, 2016 doi:10.1093/jlb/lsv059.

[16] C.H. deKogel and E.J.M.C. Westgeest 'Neuroscientific and behavioral genetic information in criminal cases in the Netherlands' *J Law Biosci* (November 2015) 2 (3): 580 -605 first published online June 23, 2015 doi:10.1093/jlb/lsv024.

[17] Research conducted by Calvin Ho, publication forthcoming.

[18] Jennifer A Chandler 'The use of neuroscientific evidence in Canadian criminal proceedings' *J Law Biosci* (November 2015) 2 (3): 550-579 first published online June 11, 2015 doi:10.1093/jlb/lsv026.

[19] Paul Catley and Lisa Claydon 'The use of neuroscientific evidence in the courtroom by those accused of criminal offenses in England and Wales' *J Law Biosci* (November 2015) 2 (3): 510 -549 first published online July 14, 2015 doi:10.1093/jlb/lsv025.

[20] The case which probably involves the most careful examination of neuroscientific evidence in alleged shaken baby cases is *R v Harris*; *R v Rock*; *R v Cherry*; *R v Faulder* [2005] EWCA Crim 1980; *R v Harris* [2006] 1 Cr App Rep 55. This case involved four appeals which were heard together. A total of 21 experts were called, 11 for the Crown and ten for the appellants. Most unusually the court's judgment contains two appendices: Appendix A contains a glossary of general medical terms and Appendix B contains annotated images of the brain.

[21] The convictions of Harris and Cherry for murder were quashed as a result of the scientific evidence.

[22] Rock's conviction for murder was reduced to a conviction for manslaughter. The scientific evidence had cast doubt on the extent of force required to cause the injuries: 'A brief period of violence (going beyond even rough play) was all that was required to cause Heidi's fatal injuries; such violence undoubtedly furnishes the mental element necessary for a conviction of manslaughter; but it does not necessarily demonstrate an intention to cause grievous bodily harm, the relevant intention if the conviction of murder was to be upheld.' *R v Harris*; *R v Rock*; *R v Cherry*; *R v Faulder* [2005] EWCA Crim 1980 [184]

[23] *R v Halling* (Jason) [2012] EWCA Crim 1774

[24] The issue was whether the head injury occurred whilst the accused and the victim were on their feet or subsequently when the victim had fallen to the floor. If the victim was still on his feet at the time of the fatal blow it would fit the defendant's plea of self-defence. However, if the victim was on the ground when the fatal blow was struck then on the facts the claim of self-defence would fail.

[25] [2005] All ER (D) 06 (Jul); *R v X (Childhood amnesia)* (2005) Times, 5 August

[26] Ibid

[27] Ibid

[28] *R v S*; *R v W* [2006] EWCA Crim 1404 [18]; [2007] 2 All ER 974

[29] [2004] EWCA Crim 1; [2005] 1 All ER 725 [22]. In this case the expert evidence was described as "absolutely critical to these convictions" [175] when it became doubted the conviction was unsafe and overturned.

[30] 57 of the 204 reported appeal cases identified by Catley and Claydon were homicide offences (27.9%). Of these 44 were cases where the defendant was initially convicted of murder.

[31] 61 of the 204 reported cases in which neuroscientific evidence was used by those accused of criminal offences were appeals solely against conviction (29.9%) and a further 20 appeals against both conviction and sentence (9.8%).

[32] 92 of the 204 cases identified were appeals solely against sentence (45.1%), to which can be added the 20 appeals against both conviction and sentence.

[33] See for example: *R v Harris*; *R v Rock*; *R v Cherry*; *R v Faulder* [2005] EWCA Crim 1980; *R v Harris* [2006] 1 Cr App Rep 55 discussed above n20; *R v X* [2005] All ER (D) 06 (Jul); *R v X (Childhood amnesia)* (2005) Times, 5 August discussed above n25 and see *R v Sharif (Mohammed)* [2010] EWCA Crim 1709 discussed below n55.

[34] The appeal against conviction was unsuccessful in 70% of cases. (59 out of 84).

[35] Nita Farahany's research into the use of neuroscientific and behavioural genetic evidence over the period 2005-2012 found 1585 cases where such evidence was used by criminal defendants. Similar methodology was used for both the English and the US research both used similar search terms and both relied on legal databases which primarily cover appeal cases. Allowing for the difference in population (USA c.323 million cf. England and Wales c.57.4 million - sources for the USA the US census bureau population clock <http://www.census.gov/popclock/> and for England and Wales the Office for National Statistics Annual Mid-year Population Estimate for 2014 <http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopu> 06-25 (both accessed 12th March 2016) the number of identified cases is broadly similar.

[36] Taylor, J. Sherrod; Harp, J. Anderson; Elliott, Tyron, Neuropsychologists and neurolawyers. *Neuropsychology*, Vol 5(4), Oct 1991, 293-305. <http://dx.doi.org/10.1037/0894-4105.5.4.293>. At this time the focus was on what neuroscience could provide to assist the law in traumatic brain injury cases.

[37] On the medical side the use of terms such as: "neuropsychology", "neuropsychiatry", "neurobiology" and "neuropharmacology" are well established and whilst in some cases having origins in the study of the nervous system now all clearly benefit significantly from advances in cognitive neuroscience. Elsewhere the prefix is seen for example in: "neuroeconomics", "neuromarketing", "neurophilosophy" and "neuroethics". In these disciplines opinion remains divided as to whether cognitive neuroscience is providing important new insights which transform the subject area or whether the impact is in fact much less.

[38] Four quotations illustrate their view: (1) "The net effect of this influx of scientific information will be a rejection of free will as it is ordinarily conceived, with important ramifications for the law." Joshua Greene and Jonathan Cohen 2004 'For the law, neuroscience changes nothing and everything', *Philosophical Transactions of the Royal Society B* 359, 1775, 1776 (2) "when it comes to the issue of free will itself, hard determinism is mostly correct. Free will, as we ordinarily understand it, is an illusion." Ibid, 1783 (3) "It is possible, however, that neuroscience will change these moral intuitions by undermining the intuitive, libertarian conceptions of free will on which retributivism depends." Ibid, 1783 (4) "Free will as we ordinarily understand it is an illusion generated by our cognitive architecture." Ibid, 1784. Greene and Cohen go on to use their understanding of neuroscience to argue that the law should abandon retributivist approaches to punishment and adopt consequentialist approaches. The emphasis of Greene and Cohen on free will has been criticised, most notably by Stephen Morse see in particular: Stephen J. Morse 'The Non-Problem of Free Will in Forensic Psychiatry and Psychology' [2007] 25 *Behav. Sci. & L.* 203. Morse is correct in noting that the Anglo-American courts rarely refer to freewill. However, as noted in the quotes from Blackstone, Hart and the Law Commission discussed below, law is based on an assumption that people have choice - an assumption that is challenged if one accepts a hard determinist viewpoint.

[39] Whilst hard determinism has had to cope with quantum indeterminacy this does not help resurrect free will. The laws of nature may be more complex than previously thought. There may be a need to acknowledge a certain randomness at the sub atomic particle level. But this does not mean that free will is suddenly restored to the hard determinist's equation.

[40] W. Blackstone, Blackstone's Commentaries on the Laws of England, Book IV - Chapter II: Of the Persons Capable of Committing Crimes.

[41] H.L.A. Hart, 1968, *Punishment and Responsibility*. Oxford: Clarendon, 181

[42] Law Commission, Criminal Liability: Insanity and Automatism - A Discussion Paper (Law Com, 2013) para 4.35.

[43] The Law Commission Discussion Paper proposes a change to the law so that an individual who wholly lacks capacity to control his actions should have a defence. If the lack of capacity arose from a qualifying recognised medical condition the defendant would be entitled to a not criminally responsible by reason of a recognised medical condition verdict. If the lack of capacity did not arise from a recognised medical condition, then the defendant would be entitled to a not guilty verdict. Ibid proposal 3 para 10.8. and proposal 13 para 10.18.

[44] For authors who have developed the idea that free will is an illusion see for example: Daniel Wenger, *The Illusion of Conscious Will* (MIT Press 2002).

[45] See for example Walter Sinnott-Armstrong and Lynn Nadel (eds) *Conscious Will and Responsibility: A Tribute to Benjamin Libet* (OUP 2010). In particular, see the chapters within the book by Larry Alexander, 'Criminal and Moral Responsibility and the Libet Experiments', Adina L. Roskies, 'Why Libet's Studies Don't Pose a Threat to Free Will' and Gideon Yaffe 'Libet and the Criminal Law's Voluntary Act Requirement'. It should also be noted that Benjamin Libet, himself, did not view his experiment as necessarily denying the existence of free will: see his chapter entitled 'Do We Have Free Will' in the same edited collection.

[46] Benjamin Libet, 'Can Conscious Experience Affect Brain Activity' *Journal of Consciousness Studies* (2003) 10: 12, 24

[47] There are occasions where the law does not hold individuals responsible for their choice - for example the English common law defences of self-defence and of duress. Similarly the existence of an age of criminal responsibility, does not deny that children have choice, but reflects a societal view that young children should not be viewed as criminally responsible.

[48] See for example Albert Einstein: "I am a determinist. As such, I do not believe in free will." (letter to Paul Ehrenfest (1928). Similarly, "I do not believe in free will." Albert Einstein *My Credo* (1932). Daniel Dennet assembles a range of similar quotes in his lecture *Is Free Will an Illusion? What Can Cognitive Science Tell Us?* at the Santa Fe Institute available online at <https://www.youtube.com/watch?v=wGPIzSe5cAU> accessed 5 April 2016 including: Wolf Singer: "No one is responsible for their action since all is predetermined by the brain". Colin Frith: "Is it possible to predict people's actions on the basis of neural activity that precedes their conscious decisions? If so, then free will is an illusion." Stephen Hawking: "Recent experiments in neuroscience support the view that it is our physical brain, following the laws of science, that determine our actions, and not agency that exists outside those laws. ... It is hard to imagine how free will can operate if our behavior is determined by physical law, so it seems that we are no more than biological machines and that free will is just an illusion." Albert Einstein: "A being endowed with higher insight and more perfect intelligence, watching man and his doings, would smile about man's illusion that he was acting according to his own free will."

[49] Definitions of compatibilism vary, but Greene and Cohen's simple definition provides a good basis. They define compatibilists as arguing that "free will and determinism are perfectly compatible" Joshua Greene and Jonathan Cohen 2004 'For the law, neuroscience changes nothing and everything', *Philosophical Transactions of the Royal Society B* 359, 1775, 1776

[50] Greene and Cohen's simple definition of incompatibilism is: "the thesis that free will and determinism are incompatible". Ibid.

[51] The scenarios often appear to be set in the United States.

[52] The M'Naghten Rules arise from the House of Lords calling the most senior judges of the day to explain the decision in the case of Daniel M'Naghten. M'Naghten had been found not guilty by reason of insanity after he shot and killed Edward Drummond, the Prime Minister's private secretary. Answering on behalf of the majority of the judges the Lord Chief Justice, Lord Tindal, explained that: 'jurors ought to be told in all cases that every man is to be presumed to be sane and to possess a sufficient degree of reason to be responsible for his crimes until the contrary be proved to their satisfaction, and that to establish a defence on the ground of insanity it must be clearly proved that, at the time of the committing of the act the party accused was labouring under such a defect of reason, from disease of the mind, as not to know the nature and quality of the act he was doing, or, if he did know it, that he did not know he was doing what was wrong.' *M'Naghten's Case* [1843-60] All ER Rep 229, 233. This explanation has since been applied many times by the courts in England and Wales, and has also influenced the development of the defence of insanity in many other jurisdictions.

[53] Indeed, expert medical evidence predates the M'Naghten Rules. For example, eight medical witnesses gave evidence at M'Naghten's trial in support of the contention that he was acting under a partial delusion: *R v M'Naghten* Old Bailey Proceedings Online (www.oldbaileyonline.org, version 7.2, 26 January 2016), February 1843, trial of DANIEL M'NAUGHTEN (t18430227-874) (accessed 26th January 2016)

[54] The old test of diminished responsibility as set out in s2 of the Homicide Act 1957 prior to its amendment by the Coroners and Justice Act 2009

[55] (1) A person ("D") who kills or is a party to the killing of another is not to be convicted of murder if D was suffering from an abnormality of mental functioning which -

(a) arose from a recognised medical condition

(b) substantially impaired D's ability to do one or more of the things mentioned in subsection (1A), and

(c) provides an explanation for D's acts and omissions or being a party to the killing.'

(Coroners and Justice Act 2009, s.52)

[56] [2010] EWCA Crim 1709

[57] Ibid [6]

[58] Under the rules at the time the question was couched in archaic terminology and turned on whether he was 'mute of malice' (i.e. choosing to be mute) or 'mute by visitation of God' (i.e. genuinely mute). 'Mute' in this context meaning not necessarily silent, but rather that he was unable to contribute to the trial process

[59] The Court of Appeal was provided with evidence by those who knew Mr. Saunders, by the Governor of the prison at which he was being held and by medical witnesses that Saunders' medical condition was a cause for concern. The court concluded "on the balance of probabilities, that the appellant Saunders is suffering from pre-senile dementia and that he was so suffering, although obviously in a considerably less acute form, last summer when the judge passed sentence." *R v Saunders and another* The Independent 17 May 1991

[60] John Shepherd, 'Forget Alzheimer's - Saunders' Independent 30th December 1994 - available online at: <http://www.independent.co.uk/news/forget-alzheimers-saunders-1388784.html> accessed 30 March 2016; Steve Boggan, 'Lucky Ernie - from dazed old man to rich adviser' Independent 17th December 1996 available on line at: <http://www.independent.co.uk/news/lucky-ernie-from-dazed-old-man-to-rich-adviser-1314871.html> accessed 30 March 2016.

[61] The idea of early release was clearly within the contemplation of the Court of Appeal; Neill LJ having commented: "We have no doubt that the medical condition of Saunders will be fully and carefully kept under scrutiny and that, if his condition justifies it, the authorities will take the appropriate steps in the future." *R v Saunders and another* The Independent 17 May 1991

[62] This included three decisions of the House of Lords: (1) *R v Bartle and the Commissioner of Police for the Metropolis and Others, Ex Parte Pinochet* [1998] UKHL 41; also sub nom *R v Bow Street Metropolitan Stipendiary Magistrate, Ex Parte Pinochet Ugarte* [2000] 1 AC 61. (2) *Re Pinochet* [1999] UKHL 52; also sub nom *R v Bow Street Metropolitan Stipendiary Magistrate, Ex Parte Pinochet Ugarte* (No. 2) [2000] 1 AC 119. (3) *R v Bartle and the Commissioner of Police for the Metropolis and Others, Ex Parte Pinochet* [1999] UKHL 17; also sub nom *R v Bow Street Metropolitan Stipendiary Magistrate, Ex Parte Pinochet Ugarte* (No. 3) [2000] 1 AC 147.

[63] BBC News, 'Pinochet "unfit to stand trial"', (*BBC News*, 12 January 2000) <http://news.bbc.co.uk/1/hi/uk/599526.stm> accessed 5 April 2016.

[64] BBC News, 'Pinochet arrives in Chile', (*BBC News*, 3 March 2000) <http://news.bbc.co.uk/1/hi/world/americas/664514.stm> accessed 5 April 2016.

[65] At his appeal one of the doctors who had examined him, Mr. Gooddy, expressed the view that: 'Mr Saunders is suffering from a form of pre-senile dementia. Mr Saunders certainly has a considerable degree of brain atrophy, as shown by the CCMRI scanning, and, more importantly, by clinical findings.' *R v Saunders and another* The Independent 17 May 1991

[66] Jeremy Warner, 'Profile: Ernest Saunders; Out of jail and back in business' The Independent 17 May 1996

[67] His step daughter's age is not given in Burns and Swerdlow's case study, but she is described as being pre-pubescent. For the purposes of the identification of the likely criminal offences applicable on the facts in English law it has been assumed that she was under 13. If she was 13 or over other offences carrying lesser maximum sentences would apply. On the facts he could also be guilty of 'Sexual activity with a child family member' contrary to section 25 and/or 'Inciting a child family member to engage in sexual activity' contrary to section 26 of the Sexual Offences Act 2003. Assuming there was no penetration these offences would carry a maximum sentence of five years' imprisonment.

[68] Sexual Offences Act 2003 s.7

[69] Ibid s.9

[70] Law Commission, Criminal Liability: Insanity and Automatism. A Discussion Paper 2013

[71] Ibid. See in particular Proposal 3, para 4.160

[72] Belgium and Luxembourg have an age of criminal responsibility of 18, Spain and Portugal 16, Norway, Finland, Sweden and Denmark 15 and Italy and Germany 14. For a discussion of approaches see: Howard League for Penal Reform, *Punishing Children: A survey of criminal responsibility and approaches across Europe* (2008)

[73] Royal Society (2011) *Brain Waves Module 4 Neuroscience and the Law*, 12

[74] The Royal Society comment that: "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". Royal Society (2011) *Brain Waves Module 4 Neuroscience and the Law*, 12

[75] Crime and Disorder Act 1998 s.34.

[76] [2009] UKHL 20

[77] 'Children in the 20th Century had to go to school where they were supposed to be taught right from wrong.' Lord Phillips [2009] UKHL 20 [20]

[78] These are arguments not based on the particular appellant's brain, but rather on the general scientific understanding of the development of the juvenile brain

[79] In contrast Catley and Claydon's research over the same time period in England and Wales found no reported cases where general developing brain theories were used on behalf of juvenile defendants.

[80] 543 US 551 (2005)

[81] 560 US 48 (2010)

[82] 567 US (2012)

[83] A New Homicide Act for England and Wales? (2005) Law Commission Consultation Paper No 177 and Murder, Manslaughter and Infanticide (2006) Law Com No 304

[84] Lord Phillips of Worth Matravers, "Reforming the Law of Homicide", Essex University/Clifford Chance lecture (6 Nov 2008) p 15 quoted in Law Commission, Criminal Liability: Insanity and Automatism. A Discussion Paper 2013 para 9.7

[85] Papers referred to by the Law Commission included: S-J Blakemore and S Choudhury, "Brain Development During Puberty" (2006) 9; *Developmental Science*, 11; E Farmer, "The Age of Criminal Responsibility: Developmental Science and Human Rights Perspectives" (2011) 6(2) *Journal of Children's Services* 86. P Kambam and C Thompson "The Development of Decision-Making Capacities in Children and Adolescents: Psychological and Neurological Perspectives and their Implications for Juvenile Defendants" (2009) 27(2) *Behavioral Sciences and the Law* 173; T A Maroney, "Adolescent Brain Science and Juvenile Justice" in M Freeman (ed), *Law and Neuroscience, Current Legal Issues 2010* (vol 13, 2011); L S Miller-Wilson, "Law and Adolescence: Examining the Legal and Policy Implications of Adolescent Development Research for Youth Involved in the Child Welfare, Juvenile Justice, or Criminal Justice Systems" (2006) 79(2) *Temple Law Review* 317; M Moreno and M Trainor, "Adolescence Extended: Implications of New Brain Research on Medicine and Policy" (2013) 102 *Acta Paediatrica* 226; Royal Society *Brain Waves Module 4: Neuroscience and the Law* (Dec 2011); E S Scott and T Grisso, "The Evolution of Adolescence: A Developmental Perspective on Juvenile Justice Reform" (1997-1998) 88 *Journal of Criminal Law and Criminology* 137; C Walsh, "Youth Justice and Neuroscience: a Dual-use Dilemma" (2011) 51(1) *British Journal of Criminology* 21.

[86] *Meah v McCreamer* [1985] 1 All ER 367.

[87] Meah was awarded £100,000 for being imprisoned for life. He was subsequently sued by two of his victims see: *W v Meah*; *D v Meah and another* [1986] 1 All ER 935. He attempted (but failed) to recover the compensation he was ordered to pay to his victims from the car insurers see: *Meah v McCreamer (No.2)* [1986] 1 All ER 947

[88] *Gray v Thames Trains Ltd. and another* [2009] UKHL 33, [2009] 4 All ER 81

[89] The principle is normally referred to in English law by reference to the Latin phrase: "ex turpi causa non oritur action", often shortened to "ex turpi causa".

[90] For example, the definitions of 'moderate brain damage' and 'less severe brain damage' both refer inter alia to: 'personality change' as one of the factors that will lead to that particular categorisation and level of compensation. More severe personality changes may push the categorisation into the more serious 'moderate brain damage' category.

[91] Guidelines for the assessment of general damages in personal injury cases thirteenth edition (2015)

[92] Where there is minimal or no brain damage the award will be low (up to £10,670).

[93] *R v Cannings* [2004] EWCA Crim 1

[94] *R v Harris*; *R v Rock*; *R v Cherry*; *R v Faulder* [2005] EWCA Crim 1980. Two of the appellants had been advised that they might want to consider appealing.

[95] See for example: Tor D. Wager, Lauren Y. Atlas, Martin A. Lindquist, Mathieu Roy, Choong-Wan Woo, and Ethan Kross, 'An fMRI-Based Neurologic Signature of Physical Pain' *N Engl J Med* 2013; 368:1388-1397; Vitaly Napadow, Lauren LaCount, Kyungmo Park, Sawsan As-Sanie, Daniel J. Clauw and Richard E. Harris 'Intrinsic brain connectivity in fibromyalgia is associated with chronic pain intensity' *Arthritis & Rheumatism* 2010; 62, 8 2545-2555; Baliki MN, Chialvo DR, Geha PY, Levy RM, Harden RN, Parrish TB, *et al.* 'Chronic pain and the emotional brain: specific brain activity associated with spontaneous fluctuations of intensity of chronic back pain.' *J Neurosci* 2006; 26: 12165-73; Tracey I. 'Imaging pain'. *Br J Anaesth* 2008; 101: 32-9

[96] Department of Health (February 2014). 2012-13 Programme budgeting benchmarking tool.

[97] Office for National Statistics (2014). Full report: Sickness absence in the labour market, February 2014.

[98] N Maniadakis *et al.* (2000). The economic burden of back pain in the UK, *Pain* 84(1): 95-103.

[99] For an excellent timeline showing the chronology of events see:
<http://www.pbs.org/wgbh/frontline/article/timeline-the-nfls-concussion-crisis/> accessed 31 March 2016.

[100] For example, Chicago Bears' fullback Merrill Hoge who retired in 1994 two weeks after sustaining a serious head injury and Dallas Cowboys' quarterback Troy Aikman who cited concussions and back problems when retiring in 2001.

[101] Including former Pittsburgh Steeler Terry Long in 2005, former Philadelphia Eagle Andre Waters in 2006, Chicago Bears' Dave Duerson in 2011, former Atlanta Falcons' safety Roy Easterling in 2012 and also in 2012 Junior Seau the former linebacker for the San Diego Chargers, Miami Dolphins and New England Patriots.

[102] See for example, NFL, 'What is a concussion' available on line at: <https://www.documentcloud.org/documents/802804-3-nfl-concussion-pamphlet.html> accessed 5 April 2016 which stated, inter alia, that "Current research with professional athletes has not shown that having more than one or two concussions leads to permanent problems if managed properly."

[103] Changes have included alterations to the return to play rules following concussion: Associated Press, 'Goodell issues memo changing return-to-play rules following concussion' 2 Dec 2009 available on line at: <https://www.documentcloud.org/documents/802804-3-nfl-concussion-pamphlet.html> accessed 5 April 2016. Changes have also been made for safety reasons to move kick-offs to the 35 yard line: NFL.com Wire Reports, 'NFL moves kickoffs to 35-yard line; touchbacks unchanged' 22 March 2011 available on line at: <http://www.nfl.com/news/story/09000d5d81ee38c1/article/nfl-moves-kickoffs-to-35yard-line-touchbacks-unchanged> accessed 5 April 2016. Perhaps most notably "crown of the helmet" tackles outside the tackle box have been banned: NBC Sports, 'NFL officiating video stresses new "crown of the helmet" rule' 6 August 2013 available on line at: <http://profootballtalk.nbcsports.com/2013/08/06/nfl-officiating-video-stresses-new-crown-of-the-helmet-rule/> accessed 5 April 2016

[104] Mark Adams of the International Olympic Commission explained the banning of head guards for male boxers at the 2016 Rio Olympics: "AIBA provided medical and technical data that showed the number of concussions is lower without headgear. They have done a lot of research in the last three years. The rule will go ahead for Rio." His comments can be found on the BBC Sport website 1 March 2016 see: <http://www.bbc.co.uk/sport/boxing/35701948> accessed 5 April 2016

[105] See for example, Hugh Godwin, 'Concussion: Does rugby union need to learn from the NFL?' *The Independent* 9 January 2016 available on line at: <http://www.independent.co.uk/sport/rugby/rugby-union/concussion-does-rugby-union-need-to-learn-from-the-nfl-a6804191.html> accessed 5 April 2016

[106] See for example: Maria Hartwig, Charles F. Bond Jr., 'Why do lie-catchers fail? A lens model meta-analysis of human lie judgments.' (2011) *Psychological Bulletin*, 137 (4) 643 or Charles Kraut 'Humans as lie detectors; some second thoughts', *Journal of Communication*, 30:209

[107] In the USA two of the leading companies involved in neuroscientific lie detection are No Lie MRI (see: <http://noliemri.com/> accessed 5 April 2016) and Cephos (see: <http://cephosdna.com/about/> accessed 5 April 2016). Stephen Laken, Cephos' founder, was involved in the *Semrau* case discussed below.

[108] 293 F. 1013 (D.C. Cir 1923) 1013

[109] Ibid

[110] Ibid, 1014

[111] Lagnleben, D.D., Hakun, J.G., Seelig, D., Wang, A.L., Ruparel, K., Bilker, B.B. and Gur, R.C. 'Polygraphy and functional magnetic resonance imaging in lie detection: a controlled blind comparison using the concealed information test.' *J Clin Psychiatry* (2016) 10.4088/JCP.15m09785

[112] See for example: Joseph R. Simpson 'Functional MRI Lie Detection: Too Good to be True?' *J Am Acad Psychiatry Law* 36:4:491-498 (December 2008)

[113] See for example: Farwell LA, Smith SS, 'Using brain MERMER testing to detect knowledge despite efforts to conceal.' *J Forensic Sci* 46 (1): 135-143 Jan 2001.

[114] For example, Iacono, William, G. 'The Forensic Application of "Brain Fingerprinting": Why Scientists Should Encourage the Use of P300 Memory Detection Methods', *The American Journal of Bioethics*, (2008) 8: 1, 30

[115] See for example: A Giridharadas, 'India's Novel Use of Brain Scans is Debated', *New York Times*, Sept 14, 2008 and David Cox, 'Can brain waves reveal you are a liar?' *BBC future* Jan 25 2016 <http://www.bbc.com/future/story/20160125-is-it-wise-that-the-police-have-started-scanning-brains>

[116] Decision of the Supreme Court of India, New Delhi, 5 May 2010 that provided The National Human Rights Commission's 'Guidelines for the Administration of Polygraph Test (Lie Detector Test) on an Accused' are adhered to evidence gathered whether by polygraphs, narcoanalysis or Brain Electrical Activation Tests can be admissible.

[117] See for example: Henry T. Greely and Judy Illes, *Neuroscience-Based Lie Detection: The Urgent Need for Regulation*, Am. J. Law & Med. 33:377-431 (2007) which suggests that the First, Fourth, Fifth and Sixth Amendments all may be engaged.

[118] See for example: Ed Johnson, 'Brain Scanning and Lie Detection: The Implications for Fundamental Human Rights' in this publication

[119] The Offender Management Act 2007 sections 28-30

[120] See n. 118

[121] In England and Wales such evidence may be taken without consent (Police and Criminal Evidence Act 1984 sections 61 - 63)

[122] Henry T. Greely, The Social Effects of Advances in Neuroscience: Legal Problems, Legal Perspectives in *Neuroethics, Defining the Issues in Theory, Practice and Policy* (Judy Illes ed) 2005, 245

[123] For a discussion of many of the issues see for example: Marks, Jonathan H., [Interrogational Neuroimaging in Counterterrorism: A No-Brainer or a Human Rights Hazard](#) 33 *Am. J.L. & Med.* 483 (2007)

[124] Ibid and see also: Jonathan D. Moreno, *Mind Wars: Brain Research and National Defence* (2006) Dana Press

[125] *United States v Semrau* United States Court of Appeals for the Sixth Circuit, 693 F.3d 510 (6th Cir 2012)

[126] *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 113 S.Ct. 2786, 125 L.Ed.2d 469 (1993)

[127] Rule 403 provides for the exclusion of evidence on grounds of prejudice, confusion or waste of time.

[128] Under English law there is a common law rule excluding previous consistent or self-serving evidence see: *R v Roberts* [1942] 1 All ER 187

[129] Or other determiner of the facts.

[130] Particularly where opportunities to benefit are open to all.

[131] For examples these products available on the internet see for example:

<https://thebrainstimulator.net/> or <http://www.diytdcs.com/> (both accessed 12th March 2016)

[132] Horvath, Jared; Forte, Jason; Carter, Olivia (2015). "Quantitative Review Finds No Evidence of Cognitive Effects in Healthy Populations From Single-session Transcranial Direct Current Stimulation (tDCS)". *Brain Stimulation* 8: 535-50, Horvath, Jared; Forte, Jason; Carter, Olivia (2015). "Evidence that transcranial direct current stimulation (tDCS) generates little-to-no reliable neurophysiologic effect beyond MEP amplitude modulation in healthy human subjects: A systematic review." *Neuropsychologia* 66: 213.

[133] Claims made, for example, for Modafinil.

[134] For example, the use of drugs in the treatment of Attention Deficit Hyperactivity Disorder - see Zuvekas SH, Vitiello B. Stimulant medication use in children: a 12-year perspective. *Am J Psychiatry* 2012; 169: 160

[135] See for example: 'Tony Nicklinson: Let doctors help me die' BBC Health 18 June 2012 <http://www.bbc.co.uk/news/health-18499878> accessed 5 April 2016. Under English law suicide is lawful, but it is against the law to assist someone to commit suicide. Patients with locked in syndrome and others who are physically incapable of committing suicide are therefore in a different position to their more able-bodied peers. Whilst they can refuse treatment, including life-sustaining treatment; if, like Tony Nicklinson, they simply want the right to bring their lives to an end they cannot do so.

[136] *R (on the application of Nicklinson and another) v Ministry of Justice ; R (on the application of AM) v Director of Public Prosecutions* [2014] UKSC 38; [2015] AC 657

[137] In a free vote on 11 September 2015 Members of Parliament in the House of Commons voted by 330 votes to 118 against the Assisted Dying Bill which would have allowed people with fewer than six months to live to be prescribed a lethal drugs dose. Patients given such a prescription would have had to be able to administer the drugs themselves. Patients, like Tony Nicklinson who had locked in syndrome, would not have benefitted from the proposed reform because they could not administer the drugs themselves and typically would have a life expectancy of more than six months.

[138] "To my mind, the difference between administering the fatal drug to a person and setting up a machine so that the person can administer the drug to himself is not merely a legal distinction. Founded as it is on personal autonomy, I consider that the distinction also sounds in morality. Indeed, authorising a third party to switch off a person's life support machine, as in *Bland* or *Re B (Treatment)* seems to me, at least arguably, to be, in some respects, a more drastic interference in that person's life and a more extreme moral step, than authorising a third party to set up a lethal drug delivery system so that a person can, but only if he wishes, activate the system to administer a lethal drug." Per Lord Neuberger *R (on the application of Nicklinson and another) v Ministry of Justice; R (on the application of AM) v Director of Public Prosecutions* [2014] UKSC 38 [94]; [2015] AC 657 [94].

[139] For example, 'Is your father's name Alexander?' For details of the methodology adopted see Martin M. Monti, Audrey Vanhaudenhuyse, Martin R. Coleman, Melanie Boly, John D. Pickard, Luaba Tshibanda, Adrian M. Owen, and Steven Laureys, 'Willful Modulation of Brain Activity in Disorders of Consciousness' (2010) *N Engl J Med* 362: 579

[140] For example, under English law a mentally competent individual has the right to refuse treatment, including life-sustaining treatment. If an individual is not mentally competent then under the Mental Capacity Act 2005 a decision will be made in the individual's best interest. In ascertaining

the patient's best interests, the patient's wishes and feelings will be one of the factors taken into account. For patients in MCS or VS the patients wishes and feelings have so far (see for example: *W by her litigation friend, B v M (by her litigation friend, the Official Solicitor) and others* [2011] EWHC 2443) always looked back to their expressed views prior to entering MCS or VS. The technological advances achieved in allowing limited communication with some of those in MCS and VS potentially could enable patients to express their current preference. For a fuller discussion of this see: Paul Catley and Stephanie Pywell 'The ethical imperative of ascertaining and respecting the wishes of the minimally conscious patient facing a life or death decision.' [2015] *Jahrbuch für Wissenschaft und Ethik*, 19 (1): 77