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Neuroimaging in criminal trials and the role of psychiatrists expert witnesses: A case study

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ABSTRACT

Various neuroscientific techniques are increasingly being used in criminal courts causing a vivid debate on the way that this kind of techniques will and should be used as scientific evidence. The role of experts in this context is important, since it is them that analyse, present, interpret and communicate the results of these techniques to the judges and the jury.

In an attempt to contribute to the discussion about the role of the experts in criminal cases where neuroimaging evidence was introduced, we examined twenty seven cases from the US and Europe. Focusing on the role of experts and their presentation of neuroscientific evidence, we aimed to examine the extent to which neuroimaging data can contribute to the construction of a solid and more objective, "scientifically - based" case.

We found that neurobiological information introduced through experts' testimony is generally used in order to demonstrate some physical, organic base of a psychiatric condition, or/and in order to make visible some brain lesion, (structural or functional), susceptible to have affected the capacity to reason and to control one's impulses. While neuroimaging evidence is often presented by the defence as a scientific method able to offer a precise diagnosis of the pathology in question, our case analysis shows that the very same neurobiological evidence can be interpreted in different - sometimes diametrically opposed - ways by defence and State experts. Conflicting testimony about the same empirical evidence goes against the hypothesis of neuroscientific techniques constituting "objective and hard evidence", able to reach solid, scientific and objective conclusions.

Frequent conflicts between neuroimaging experts require the courts to deal with the resulting uncertainty. As the law changes with technology, it is necessary for legal professionals to train and be prepared for the new issues they may encounter in light of new developments in neuroscience, so that they become more vigilant as to the interpretation of neuroscientific data.

1. Introduction

Various neuroscientific methods and techniques are increasingly being used in criminal courts causing a vivid debate on the way in which this kind of techniques will or should be used as scientific evidence. Clinical neuropsychologists and psychiatrists engage increasingly in forensic consulting activities because such expert opinions are generally relevant, reliable and helpful in resolving certain legal claims, especially those related to traumatic brain injury (Kaufman, 2013). Neurotechnologies are defended as being useful in terms of objectivity and completeness (Sirgiovanni et al., 2016) and neuroscientific evidence is often perceived as more objective, reliable and "scientific" evidence. (See Tables 1 and 2.)

Complaints about the unreliability of scientific evidence used in courts worldwide are long-standing (Neufeld & Sheck, 2010) and forensic psychiatry faces numerous criticisms concerning the epistemological limitations of psychiatric evaluations and their subjectivity, that prevents psychiatrists from establishing a precise diagnosis of mental pathology (Gkotsi & Gasser, 2016). In this context, rise of neuroscience in criminal courts raises hopes for the construction of a more objective and reliable criminal justice system and neuro-genetic evidence is considered by many authors as a useful tool for a more objective evaluation of the degree of criminal responsibility and of the dangerousness of the defendant.

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Table 1
Reasons of introduction of neuroscientific data in psychiatric expertise/testimony.

Reasons of introduction of neuroscientific data in psychiatric expertise/testimony	Total number of cases
To diagnose a specific psychiatric pathology revealing its cerebral basis	11
To demonstrate brain damage (without reference to a specific psychiatric pathology)	11
Causes of brain damage:	
Traumatic Brain Injury	8
Cognitive disorders	3
Comorbidity of psychiatric conditions, head trauma, addiction and cognitive disorders	5

Table 2
Rebuttal opinion testimony: reasons for state experts disputing neuroimaging evidence.

Rebuttal opinion testimony: reasons for state experts disputing neuroimaging evidence	Total number of cases
Experts question the capacity of neuroimaging techniques to diagnose a specific psychiatric pathology or brain injury	7
Experts disagree over the interpretation of neuroimaging findings	9
Experts contest the adding value/relevance of brain imaging techniques	2
Experts disagree on the relation between the brain disorder and violent behavior	7
Experts disagree on the extent to which existing brain damage affected responsibility	2

Although application of neuroimaging techniques in forensic psychiatry is in its infancy, some authors claim that there is a great need to develop forensic evaluation techniques that are more informed by neurobiological and "objective" criteria. According to them, taken together, behavioral, neuropsychological and/or neuroimaging evidence could paint a rich portrait of a defendant's brain dysfunction and its causal role in the criminal behavior in question (Nadelhoffer & Armstrong, 2012; Witzel, 2012; Witzel et al., 2008; Silva, 2009; Simpson, 2012).

The legal system needs neuroscientists to act as experts or expert witnesses who can explain the limitations and interpretations of neuroscientific findings. The role of experts in this context is important, since it is the experts that analyse, present, interpret and communicate the results of these techniques to the judges and the jury, so that the latter can make informed and appropriate inferences (Jones et al., 2013).

Use of neuroscientific data in criminal proceedings is widespread in the US, where neuroscience is entrenched in the legal system as several studies suggest (Farahany, 2009; Denno, 2015). Neuroimaging methods and techniques have also made appearance in the courts of Canada and Europe, but the extent of their use, especially in Europe, is not known. For a long time, much of the discussion concerning the use of neuroscience to the criminal justice system remained speculative (Catley & Claydon, 2016) while until recently, especially in Europe, empirical case law data were rare, with the exception of individual high profile cases.[1]

Some recent studies filled this gap in current scholarship, examining an abundant number of cases in several countries, such as UK, Netherlands and Canada, in order to assess the extent of usage of neuroscientific evidence in criminal courts (Catley & Claydon, 2016; de Kogel and Westgeest, 2016; Chandler, 2016). These studies focus on the outcome of neuroscientific evidence on the judge's decision and sentencing and aim to explore whether the use of such evidence is increasing, declining, or remaining constant, as well as the extent to which it is being used successfully.

Despite the importance of the role of experts in these procedures, there exists a shortage of studies focusing on experts and the way in which neuroimaging evidence is presented by experts in criminal cases. As the interdisciplinary dialog and understanding among law, medicine, and psychology/psychiatry continues to expand, there is a need to examine the role of experts in forensic consultations in cases involving neuroimaging evidence.

2. Aims

In an attempt to contribute to the discussion about the role of the experts in criminal cases where neuroimaging evidence was introduced, we conducted a case law research and examined cases from the US and Europe, where neuroimaging techniques were introduced, focusing on the role of psychiatric experts, called by both the Defence and the State.

Our general goal is to examine the way in which neuroscientific data are presented and interpreted by the experts and the extent to which the experts' testimony concerning neuroimaging data can meet up to many of "neurolaw defenders" expectations of constructing a "solid" and more objective, "scientifically - based" case.

By examining the way in which this kind of evidence is presented by defence experts, but also rebutted by State experts, we aim to verify if and to which extent this kind of evidence constitutes "hard evidence", as opposed to "soft, conventional psychiatric evidence" and to which extent neuroimaging constitutes an objective tool with significant probative value, able to prove a link between some structural or functional brain abnormality and criminal behavior.

3. Methodology

3.1. Access to the cases

Cases from the United States and the United Kingdom were searched in the standard common law legal databases, Westlaw and LexisNexis.

The two Italian cases being high profile cases, were identified in the neurolaw literature and accessed in the legal journal "Guida di Diritto".

Search key-terms were: "neuro-", "PET scan", "MRI", "CT scan", "EEG".

3.2. Selection criteria of the cases

We selected criminal cases in the context of which neuroscientific evidence was introduced. We defined neuroscientific evidence strictly, limiting our research to cases including neuroimaging techniques[2] and excluded cases in which general neuropsychological/neurocognitive information was introduced. We looked at cases from various countries, independently of the legal system (anglosaxon or continental) and of the crime for which the subject was tried. Five Dutch cases were excluded due to lack of available translation and three cases (two US cases and one English case) were also excluded because they did not exactly meet our selection criteria (they included information about the neurological status of accused, but no neuroimaging techniques were introduced) or because they lacked data that could be usable according to our objectives. In a total of thirty five cases, twenty seven cases were usable in terms of data and information.

[1] See for example: Gip Como, 20.05.2011, in Guida al diritto (online), 30 agosto 2011, con nota di MACIOCCHI, Gip di Como: le neuroscienze entrano e vincono in tribunal and Tribunale di Venezia, G.i.p. dott.ssa Roberta Marchiori, 24 gennaio-8 aprile 2013, sent. n. 296.

[2] We included any kind of techniques, such as Electro Encephalography (EEG), magnetic resonance imaging (MRI) structural or functional, Positron Emission Tomography (PET) scan, computed tomography (CAT scan), Single-photon emission computed tomography (SPECT scan) and Brain Electrical Activity Mapping (BEAM).

3.3. Case analysis criteria

1. From a descriptive point of view, cases were categorized according to their descriptive characteristics: type of offense, type of psychiatric pathology, type of neurological disorder, type of technique used.
2. From a thematic point of view, we analyzed the cases in light of two basic criteria:
   a. We reviewed the cases in light of the individual reasons for which neuroscientific testimonies are introduced in courts as part of psychiatric testimony; how are these techniques presented by the experts; for which reasons and for which type of pathology/condition (neurological, psychiatric, or both)?
   b. We reviewed the cases in light of the conflicting medical testimony presented: what are the reasons for which defence expert testimony including neuroimaging techniques is disputed by State experts (in common law systems) or Court appointed experts (in the two Italian cases), in the context of the same case. We analyzed State or Court appointed experts' testimony in light of their disagreement with defence experts on the diagnosis of a psychiatric or neurological disease with the aid of neuroimaging techniques, on the interpretation of neuroscientific data and results, on the adding value/relevance to the case of brain imaging techniques, on the relation between the brain disorder and violent behavior and finally on the extent to which existing brain damage affected responsibility.

4. Results

4.1. Description of cases

On a total of thirty five cases, twenty seven were usable in terms of data and information, of which twenty two come from the US, three from the UK and two from Italy.

1. Origin of cases: The vast majority of cases come from USA. We included some cases from the UK and Italy. On a total of thirty five cases collected, twenty five come from the US and ten from Europe (UK, Italy and the Netherlands).
2. Time period: the majority of cases (twenty eight) concerns the period from 2000 to 2013 and we found seven cases prior to 2000.
3. Type of offense: the type of offense is homicide/murder in all cases apart from three, which involved drug trafficking, making false statements to a bank and child sexual abuse.
4. Legal context: In European cases, on a total of five cases, three cases were on appeal. In cases from USA, neuroimaging techniques are used in various contexts: for legal insanity defenses and determining the "mens rea" of the accused (ten cases, of which eight cases are on appeal) and for mitigation purposes in the sentencing stage of the criminal procedure (in all twelve cases that we examined, the death sentence was appealed).
5. Type of psychiatric disorders: Psychiatric disorders vary: most often, we encounter those related to psychotic disorders/pathologies, such a schizophrenia, paranoid schizophrenia, bipolar disorder, psychosis, dissociative identity disorder and personality disorders, such as antisocial personality disorder and impulse control disorders, such as intermittent explosive disorder, while a post-traumatic stress syndrome (PTSD) is invoked in three cases.
6. Type of neurological disorders: frequent are the cases of brain damage due to various reasons, such as Traumatic Brain Injury, brain tumor, or subdural hematomas. There are also cases where the experts refer to the existence of cognitive disorders, and Fetal Alcohol Syndrome, while in many cases, psychiatric disorder is associated with or induced by alcohol or drug intoxication, such as Alcohol Dependency Syndrome (ADS).

4.2. Reasons of use of neuroscientific data in psychiatric expertise/testimony

Anglo-American jurisprudence assigns to the litigants the role of producing evidence, much of which is provided by witnesses whose testimony usually favours the party who is calling them. This is no less often the case when the witnesses are doctors or scientists produced by the plaintiff or the defendant (Myers, 1965). The majority of countries belonging to continental legal systems have both court-appointed experts and experts appointed by the parties, both of whom help judges to arrive at decisions by contributing their technical or scientific knowledge.

Generally, the use of neuroimaging evidence in defence psychiatric testimonies is mainly shaped by the defence strategy and closely linked to the legal context of each case. Defence counsellors hope that information about the brain of the defendant acquired with neuroimaging techniques will help them prove their legal case, be that an affirmative or negating defence on trial or an appeal.

Here are the main purposes and ways in which neuroimaging methods and techniques are introduced in psychiatric testimony in cases reviewed.

4.2.1. Neuroimaging techniques are introduced in order to diagnose a psychiatric pathology revealing its cerebral basis

Neuroimaging techniques are often introduced in order to prove the existence of an alleged psychiatric disorder, revealing its cerebral basis. In these cases, neuroimaging techniques are presented by the experts as a way to "objectify" a classic psychiatric condition from which the defendant allegedly suffers and which according to the defence has affected their responsibility.

For example, in *State v. Zimmerman*,[3] the defence attempted to introduce a Brain Electrical Activity Mapping (BEAM) technique as a complementary tool to the insanity defence, in order to prove the existence of brain abnormalities, in line with the defence experts' testimony at trial, that the defendant was psychotic and suffering from temporal lobe disorder.

People v. Goldstein[4] is characteristic in that the defence (that had raised an insanity defence) attempted to physically demonstrate the existence of the defendant's schizophrenia. A defence expert introduced a PET scan, in an effort to make visible the defendant's schizophrenia on a brain level, but the PET scan was excluded from the court. According to the defence, "*the PET scan … would have supported the expert's opinion that the defendant's brain physically manifested schizophrenia, in the form of a massive reduction in metabolism in the frontal lobe and the basal ganglia.*[5]

In *US v. Montgomery,*[6] brain imaging was introduced in the aim of bolstering the expert's testimony about the existence of the disputed psychiatric pathology of "pseudocyesis", which was invoked, among others by the defence and was strongly contested by prosecution experts. The defence introduced neuroimaging evidence (PET and MRI scans) and had the defence expert testify that the defendant's brain presented some structural and functional abnormalities consistent with the diagnosis of pseudocyesis.

In an Italian case,[7] the experts considered that the pedophile behavior of the defendant was caused by a large tumor in his brain, a clival chordoma that was evidenced by an MRI. The clival chordoma is a tumor that compresses neighboring regions, in particular the optical area, the frontal orbit, and the hypothalamus, a structure in the nervous system which among other things controls sexual behavior. In an effort to back up the defence position that the defendant's pedophilic

[3] State v. Zimmerman, 802 P.2d 1024, 166 Ariz. 325 (Ct. App. 1990).
[4] People v. Goldstein, 14 CE3d 32, 786 N.Y.S.2d 428 (App. Div. 2004), People v. Goldstein, 843 N.E.2d 727, 6 N.Y.3d 119, 810 N.Y.S.2d 100 (2005).
[5] People v. Goldstein, 14 CE3d 32, 38, 786 N.Y.S.2d 428 (App. Div. 2004).
[6] US v. Montgomery, 635 F.3d 1074 (8th Cir. 2011).
[7] Tribunale di venezia, G.i.p. dott.ssa Roberta Marchiori, 24 gennaio-8 aprile 2013, sent. n. 296.

tendencies were causally linked to the appearance of the tumor, the experts concluded that the defendant suffered from "acquired pedophilia", which according to them could be attributed to the clival cordoma.

In another Italian case,[8] following two psychiatric expert opinions, which were contradictory regarding both the mental pathology from which the defendant suffered and the degree of her responsibility, neurobiological methods were introduced as a way of objectifying a hardly diagnosable psychiatric condition. The defence requested a third expertise and the defendant was subjected to a series of psychiatric, neuropsychological and memory tests, as well as to neuroscientific and genetic analyses. According to the experts, memory tests evidenced memory deficits, suggesting the presence of a dissociative identity disorder, while EEG (electro-encephalogram) results, and VBM (Voxel-Based Morphometry) results evidenced a lack of integrity and functionality of the anterior cingulate cortex and the insula of the accused, suggesting - according to the experts - the existence of an obsessive-compulsive disorder and a predisposition to exhibit aggressive behavior.

In *Stewart v State*, the defence claimed that a PET scan that counsel had failed to obtain at trial would have established or corroborated that defendant suffered a left hemisphere, organic brain damage. The latter was considered as the source of various psychiatric conditions with which he was diagnosed, such as Attention Deficit Hyperactivity Disorder (ADHD), Post-Traumatic Stress Disorder (PTSD) and alcohol abuse. According to the defence expert, these were symptoms of behavior manifestations of the underlying problem of organic brain damage and the combination of these disorders had led to the murder.

Finally, in some cases, brain imaging evidence is offered as evidence of addiction to drugs or alcohol. For example, in *Ferrell v State*, defence experts had testified at trial that the defendant suffered from brain damage, possibly due to previous head trauma (fall) or alcoholism. In cross examination of defence expert, state experts had opined that brain damage caused by long term alcohol abuse needed to be confirmed by medical testing and that brain damage could be verified by a PET scan.

4.2.2. Neuroimaging techniques are introduced in order to demonstrate brain damage (without reference to a specific psychiatric condition)

In most cases, neuroimaging evidence is presented in court through psychiatric testimony as a means to demonstrate brain damage in specific areas of the brain, especially those related to the capacity of rationality and impulse control, i.e. generally related to the legal criteria (cognitive and volitive) for assessing criminal responsibility. The regions affected in the vast majority of the cases are fronto-temporal lobes.

The causes of the brain damage itself vary. Brain damage is often presented as a result of a head trauma or a Traumatic Brain Injury (TBI), usually due to severe beating or a previous accident.

4.2.2.1. Head trauma – traumatic brain injury. For example, in *People v. Protsman,*[9] the defence attempted to introduce a PET scan in order to diagnose "moderate to severe head trauma" due to prior Traumatic Brain Injury (TBI). According to defence experts, PET scan images indicated that the subject suffered from a decrease in frontal lobe activity and that the pattern of the images was consistent with traumatic brain injury,[10] which had affected his ability to control his impulses. According to another psychiatrist expert for the defence, damage to the frontal lobe was part of a general picture of drug induced psychosis, accentuated by previous brain injury due to two prior head accidents.

In *People v. Yum*,[11] the defence tried to show that the defendant had been physically abused by his father, "which rendered him insane at the time of the killings of his mother and sister". The purpose of defence expert testimony was to put forth evidence of a defendant's SPECT scan, in an attempt to show that there was temporal lobe damage caused by severe beating by his father. Neuroimaging expert for the defence testified that defendant's brain scan showed results associated with brain trauma.[12] He also testified that *"the scan revealed diminished activity in temporal lobe and hyperactivity elsewhere, findings which were consistent with brain trauma and correlated with predisposition to violence, anger and aggression"*.[13]

In *Trapp v Spencer*,[14] the defence presented testimony that the murder committed by the appellant was a product of an organic brain abnormality caused by earlier head traumas, due to severe beating by the defendant's father. At trial, a defence expert testified that a CT scan showed an enlarged area of his right temporal horn where '*spinal fluid fill[ed] within the temporal lobe*[15] and that because of this condition, the appellant suffered from intermittent explosive disorder and organic personality disorder. A PET scan was also introduced which showed *"mildly decreased metabolism in the medial aspects of the temporal lobe bilaterally, which was possibly related to memory impairment or inter-ictal seizure foci"*.[16]

In *People v. Kraft*,[17] a sentencing decision, a PET scan was introduced as mitigation evidence. The scan revealed abnormalities that according to the experts could have been caused by a head injury or vascular problem.

In *People v. Sapp*,[18] the neurologist for the defence introduced a BEAM showing an abnormality in defendant's middle-left posterior temporal lobe. In addition, MRI scans showed the presence of a tumor at the base of his skull, near the brain centre for impulse control. According to the defence psychiatrist, BEAM results indicated both brain damage and organic dysfunction and stated that *"damage to an individual's left temporal lobe may cause sudden mood shifts and aggressive, violent, destructive outbursts*[19]"

4.2.2.2. Cognitive disorders. In some cases, neuroimaging techniques were introduced as evidence of cognitive disorder and slow mental functioning.

In *Sandoval-Mendoza*[20] for example, an MRI scan was introduced in an attempt to demonstrate the existence of an unusually large pituitary tumor compressing frontal, temporal lobe and thalamus, allegedly responsible for the defendant's cognitive impairment and low intelligence. The latter was relevant and crucial to the entrapment defence raised by the defence.

In *Ex Parte Simpson*,[21] the defence claimed that in addition to antisocial personality disorder the defendant suffered from borderline intellectual functioning, with an IQ ranging from 71 to 78. As evidence, an EEG revealed a non-specific generalized slowing of the brain. In addition, an MRI scanning revealed two subdural hematomas which according to the defence psychologist caused brain damage, poor judgment, inability to learn from mistakes, inability to change actions in response to complicated situations and inability to control frustration or manage oneself.

In *Hoskins v State*,[22] a neuropsychologist retained by the defence determined that Hoskins had an IQ of 71 and a 'mild brain abnormality'. The defence filed a motion requesting that the defendant should be transported for a PET scan, which, according to the defence neuropsychologist would help more accurately determine the extent of Hoskins's

[8] Gip Como, 20.05.2011, in Guida al diritto (online), 30 agosto 2011, con nota di MACIOCCHI, Gip di Como: leneuroscienze entrano e vincono in tribunale.
[9] People v. Protsman, 105 Cal. Rptr. 2d 819, 88 Cal. App. 4th 509 (Ct. App. 2001).
[10] People v. Protsman, 105 Cal. Rptr. 2d 819, 822, 88 Cal. App. 4th 509 (Ct. App. 2001).
[11] People v. Yum, 3 Cal. Rptr. 3d 855 (Ct. App. 2003).
[12] People v. Yum, 3 Cal. Rptr. 3d 855, 856 (Ct. App. 2003).
[13] People v. Yum, 3 Cal. Rptr. 3d 855, 857 (Ct. App. 2003).
[14] Trapp v. Spencer, 479 F.3d 53 (1st Cir. 2007).
[15] Trapp v. Spencer, 479 F.3d 53, 56 (1st Cir. 2007).
[16] Trapp v. Spencer, 479 F.3d 53, 57 (1st Cir. 2007).
[17] People v. Kraft, 5 P.3d 68, 99 Cal. Rptr. 2d 1, 23 Cal. 4th 978 (2000).
[18] People v. Sapp, 73 P.3d 433, 2 Cal. Rptr. 3d 554, 31 Cal. 4th 240 (2003).
[19] People v. Sapp, 73 P.3d 433, 2 Cal. Rptr. 3d 554, 597, 31 Cal. 4th 240 (2003).
[20] US v. Sandoval-Mendoza, 472 F.3d 645 (9th Cir. 2006)
[21] Ex parte Simpson, 136 S.W.3d 660 (Tex. Crim. App. 2004).
[22] Hoskins v. State, 702 So. 2d 202 (Fla. 1997).

brain damage and determine whether there was a neurologic basis for his poor impulse control.[23]

4.2.3. Comorbidity of psychiatric conditions, head trauma, addiction and cognitive disorders

In the vast majority of cases, brain imaging evidence is introduced in order to bolster defenses in which a multiple diagnosis has been made and where all of the conditions described in chapters 3.2.1 and 3.2.2. - i.e. psychiatric or/and neurological conditions in combination with cognitive disorders or some form of addiction - are invoked at the same time.

For example, in *Cooper v State*,[24] Cooper was diagnosed by the defence neuropsychologist as brain damaged, suffering at the same time from mental retardation and mental illness (i.e., paranoid schizophrenia).[25] Cumulating mitigation evidence, based among other tests on neuroimaging evidence, such as EEG and CAT scan was introduced by the defence in order to objectify his condition. Defence expert opined that "*because of the defendant's brain impairment, and problems with his frontal lobe functioning, coupled with the physical and psychological abuse that he suffered from his father, and his drug abuse, the defendant was a person who was easily influenced by others to engage in behaviour that was not socially acceptable, he could appreciate the criminality of his conduct, but could not conform his conduct to the requirements of the law*".[26]

Similarly in *Robinson v State*,[27] the defendant appealed his death sentence claiming that the trial court erred in denying his request for neurological testing including a SPECT scan, which would have provided additional insight into his brain damage. Various psychiatric conditions were invoked by the defence in combination with alcohol and drug problems: a defence expert testified that Robinson suffered from Attention Deficit Disorder as a child, that he exhibited signs of antisocial personality disorder, such as unpredictability, impulsiveness, anger, suspiciousness, moodiness, and that he was a chronic drug abuser of various substances (such as alcohol, marijuana, methamphetamine, cocaine and LSD). A second defence expert, a neuropharmacologist, confirmed that the appellant had a problem of chronic drug use, whose withdrawal symptoms caused profound depression but also suffered from psychosis and described preschizophrenic processes going on his brain. These testimonies were accompanied by assertions by both experts that Robinson was suffering from apparent brain damage in the left temporal lobe.

Similarly in *State v Marshall*,[28] there was a mixed diagnosis of schizophrenia, bipolar disorder and serious brain damage. Neuroimaging evidence demonstrated a general neurocognitive dysfunction due to serious brain damage, believed by one expert to have been caused by severe head trauma due to heavy beating. More specifically, brain atrophy was indicated by several neuroimaging techniques, such as an MRI showing a significantly shrunk brain, an EEG which showed electrical activity much slower than that of a normal person and a SPECT scan revealing an abnormal blood flow to the brain.

4.3. Conflicting expert testimony concerning neuroimaging evidence: reasons for state experts disputing neuroimaging evidence

In common law cases, each party presents the rebuttal opinion testimony of own expert. Prosecution generally aims to rebut testimony given by defence-appointed scientific experts, appealing to other specialists - experts in the field of neuroscience.

When conflicting or contradictory medical testimony is presented, a phenomenon arises which often attains such noticeable proportions that it has been dramatically labeled "the battle of the experts." (Myers, 1965). In the context of criminal trials where neuroimaging evidence was introduced, this is done for different purposes, which can be categorized as follows (note that more than one of the reasons listed below can exist in the context of one single case):

4.3.1. State experts question the capacity of neuroimaging techniques to diagnose a specific psychiatric pathology or brain injury

In several cases, the prosecution questions the capacity of a specific neuroimaging technique to diagnose a psychiatric disorder from which the defendant allegedly suffers, usually because of lack of consensus in the scientific community in accordance with the Frye standard,[29] or with Daubert criteria.[30]

For example, in *People v. Protsman*, experts for the prosecution specialized in neuroimaging, questioned the ability of a PET scan to diagnose head trauma. They testified that the use of PET scan imaging for diagnosing or evaluating head trauma was investigational only and had not been validated by the neurology and brain imaging community, adding that "*use of PET scan imaging to purportedly diagnose head trauma in people who were walking and functioning and especially at a time remote from the injury was not acceptable*".[31] The experts testified that the three accepted uses of PET scans were in cases of stroke, Alzheimer's and epilepsy, and confirmed that the use of PET scans for detecting or evaluating brain traumas was not acceptable.

Likewise, in *People v Yum*, prosecution experts questioned the capacity of a SPECT scan to diagnose PTSD, testifying that the majority of qualified members in the neurology and brain imaging community does not support the use of SPECT scans to diagnose prior head trauma and mental disorders like PTSD and considers the technique generally unreliable for this purpose. The same reason was invoked in *Jackson v Calderon,* where state experts testified that the use of PET scans to diagnose chronic PCP abuse is not generally accepted by the scientific community.

In US v Montgomerry, prosecution experts explicitly questioned the defence experts' assertion that the defendant's PET scan's pattern corresponded to "pseudocyesis". They testified that the neurological profile revealed by the PET scan could be consistent to various neurological profiles, both normal and pathological and in any case would not be indicative of a specific mental illness. They added that no PET scan can indicate pseudocyesis, since in general this technique is not helpful in making any diagnosis, let alone in diagnosing a highly questioned condition, such as "pseudocyesis". In *People v Goldstein*, state expert denied that a PET scan could conclusively prove the existence of schizophrenia.

Finally, in *Schoenwetter v State*,[32] prosecution experts contested the existence of Asperger's syndrome on the basis of a PET scan, claiming that the defendant's course of conduct was not consistent with the

[23] The trial judge denied the motion asserting that a PET scan would be highly suggestive at best and that as admitted by defence expert - a PET scan would not help in determining whether such brain damage would have a causal relationship to Hoskins' commission of the crime.

[24] Cooper v. State, 739 So. 2d 82 (Fla. 1999).

[25] Cooper v. State, 739 So. 2d 82, 86 (Fla. 1999).

[26] Cooper v. State, 739 So. 2d 82, 87 (Fla. 1999).

[27] Robinson v. State, 761 So. 2d 269 (Fla. 1999).

[28] State v. Marshall, 27 P.3d 192, 144 Wash. 2d 266 (2001)

[29] Frye v. United States, 293 F. 1013 (D.C. Cir. 1923): "*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 the courts will go a long way in admitting experimental 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*"

[30] Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 US 579, 589 (1993) "*…Faced with a proffer of expert scientific testimony under Rule 702, the trial judge, pursuant to Rule 104(a), must make a preliminary assessment of whether the testimony's underlying reasoning or methodology is scientifically valid and properly can be applied to the facts at issue. Many considerations will bear on the inquiry, including whether the theory or technique in question can be (and has been) tested, whether it has been subjected to peer review and publication, its known or potential error rate, and the existence and maintenance of standards controlling its operation, and whether it has attracted widespread acceptance within a relevant scientific community*".

[31] People v. Protsman, 105 Cal. Rptr. 2d 819, 822, 88 Cal. App. 4th 509 (Ct. App. 2001).

[32] Schoenwetter v. State (2010) 46 So.3d 535 (Fla. 2010).

symptoms of Asperger's syndrome, *"furthermore, the defendant managed to avoid breaking the law up until this point in his life, despite the fact that Asperger's is a lifelong condition"*.[33]

4.3.2. Disagreement over the interpretation of the neuroimaging findings

In a number of cases, although prosecution experts do not contest the results of brain imaging as such, they interpret them differently, denying either the existence of the alleged psychiatric disorder supposedly linked with the neurological finding, or/and by denying the existence of neurological/brain "damage", invoking a different standard of brain "normality".

In *People v. Protsman* for example, one of the prosecution experts PET testified that the scan of Protsman's brain was normal and that he did not see "one single abnormality". In *Stewart v State,*[34] (where a CT scan, an MRI scan and a PET scan had been introduced in order to back up the diagnosis of PTSD, ADHD, a learning disability and alcohol abuse), state experts disagreed over the diagnosis of ADHD and brain impairment and opined that defendant suffered from PTSD, rather than ADHD at the time of the offense. They also contested the existence of brain damage itself, confirming that the PET scan was normal and that *"within reasonable medical possibility, defendant has not brain damage"*.[35]

In *People v Sapp*,[36] the state psychologist confirmed the existence of organic brain damage and brain dysfunction revealed with the aid of an MRI scan, but rather attributed them to an antisocial personality disorder, characterized by the *"lack of any restraints from societal prohibitions"*.[37] The question of "normality" was also raised in *R v Hill*,[38] where experts agreed on the kind of neurological findings, but disagreed on the extent to which these findings could be considered "abnormal", with the defence expert considering them *"beyond normal"* and prosecution expert asserting that they were *"essentially normal or within normal range"*.

In Cooper v State,[39] state experts denied the existence of both brain damage and mental illness. According to them, the CAT scan and EEG did not support any finding of injury to the brain and no objective evidence existed to support the finding that defendant suffered from any mental illness. Finally, in *R v Hendy*,[40] experts for prosecution found no signs of major psychotic mental illness, as defence experts had asserted. Although they admitted the defendant's inability to control his temper, they testified that the issue was whether the loss of temper was pathological or could be attributed to alcohol consumption.

Finally, in *US v Sandoval-Mendoza*, the neurologist testifying as a prosecution expert interpreted differently the MRI of the defendant's brain and opined that it did not show any brain damage. At the same time, the prosecution expert tried to dismiss the defence expert's testimony that the defendant's large brain tumor made him susceptible to suggestion – which was crucial for the entrapment defence raised by his lawyers – testifying that *"While some brain tumors may cause disinhibition or greater susceptibility to influence, pituitary tumors do not, unless they are even larger than the defendant's"*.

4.3.3. Experts contest the adding value/relevance of brain imaging techniques

Defendants have also premised death sentence appeals on the assertion that failure to present neuroimaging evidence constituted ineffective assistance of counsel. In most of these cases, State experts oppose to the use of neuroimaging techniques contesting their usefulness and their ability to bring additional evidence, but also their relevance for the case. Their main argument is that failure to present neuroimaging evidence did not prejudice the defendant because the neuroimaging evidence was cumulative or unnecessary in light of other expert mental health testimony presented. For example, in *Ferrell v. State*, where the issue was whether trial counsel was ineffective in failing to obtain a complete neuropsychological examination and a PET scan, state experts asserted that while a PET scan would confirm Ferrell's brain damage, a clinician would still have to discern his level of impairment. According to them, the diagnosis of intellectual impairment could be done on the basis of observations, testing, and case records, thus rendering a SPECT scan unnecessary for this purpose. Similarly, in *Robinson v. State*, the Court concluded that there was no error in the court's denial of the defendant's request for a SPECT scan, as the defence had failed to make an adequate showing of need for the neurological test requested in this case.

In *Jackson v Calderon*,[41] where the defence had attempted to introduce a PET scan in order to evidence the defendant's addiction to PCP, the prosecution expert claimed that the PET scan could not explain what effect PCP-induced brain damage would have on Jackson's capacity for higher thought and thus no evidence was introduced to suggest that a PET scan could prove that Jackson was unable to premeditate or form specific intent to kill at the time of the shooting.

4.3.4. Experts disagree on the relation between brain disorder and violent behavior

Given its importance within the legal context, the question of causality between brain findings concerning abnormalities in structure or function and criminal behavior is often raised in courts and contested in several way by State experts.

For example, in *US v Sandoval-Mendoza*, prosecution experts did not contest the existence of the neurological finding, i.e. the existence of a tumor in the defendant's brain, but denied the expert's assertion - which constituted the main defence's strategy, — that it was the tumor that was directly linked and had affected the defendant's behavior and cognition and consequently his "susceptibility to inducement".

In one of the Italian cases, defence experts considered that the defendant's brain tumor compressing some neighboring brain regions was causally linked to the behavioral and sexual disorders that he had developed since the appearance of the tumor, that is to say his pedophilic tendencies. Experts appointed by the court, however, reached a different conclusion, confirming that the tumor was indeed exerting pressure on the brain stem, but had left the orbitofrontal cortex and hypothalamus intact, and therefore could not have had an impact on the sexual sphere and the behavior of the accused. In addition, the experts rejected in principle the causal relation between a cerebral pathology and the pedophilic behavior, pointing out that there are very few cases of this type and saying that this hypothesis is experimental and scientifically limited: beyond this specific case, testing for a correlation between neural dysfunction and pedophilia has been demonstrated in only a very small number of cases (Burns & Swerdlow, 2003).

In *US v Montgomerry*, although the defence expert, when questioned, hesitated to explicitly certify that it was the defendant's brain abnormalities that caused her to commit the crime, he testified that these abnormalities contributed to her actions and that *"the brain she has may explain at least part of what's happened"*. In rebuttal, prosecution experts testified that no causal relation existed between brain functioning and the act.

4.3.5. Disagreement on the extent to which existing brain damage affected responsibility

Apart from the medical/scientific part of their testimony, experts are invited to express their opinion about the extent of responsibility of the defendants/appellants. As expected, even when they are based on the

[33] Schoenwetter v. State (2010) 46 So.3d 535, 543 n.3 (Fla. 2010).
[34] Stewart v. State (2010) 37 So.3d 243 (Fla. 2010).
[35] Stewart v. State (2010) 37 So.3d 243, 251 (Fla. 2010).
[36] People v. Sapp, 73 P.3d 433, 2 Cal. Rptr. 3d 55f4, 31 Cal. 4th 240 (2003).
[37] People v. Sapp, 73 P.3d 433, 2 Cal. Rptr. 3d 554, 598, 31 Cal. 4th 240 (2003).
[38] R v Hill [2008] EWCA Crim 76.
[39] Cooper v. State (1999) 739 So.2d 82 (Fla, 1999).
[40] R v Hendy [2006] EWCA Crim.
[41] Jackson v. Calderon (2000) 211 F.3d 1148 (9th Cir. 2000)

same evidence, experts disagree radically about their interpretation and its implications for the defendants' responsibility.

In one Italian case, the defence experts concluded that the existence of irresistible impulses that the defendant could not control (volitional inability) combined with his inability to understand the socially unacceptable nature of his behavior (cognitive inability) as a result of the tumor in his brain showed that the accused could not have acted differently and that he was not responsible according to article 88 of the Italian penal code (*vizio totale di mente*). However, the supposedly empirical evidence provided by the fMRI was also analyzed by experts requested by the prosecution, who presented radically different conclusions than those of the defence. The prosecution's experts determined that there was a tumor; however, it did not create pressure on the orbitofrontal lobe but rather on the pons Varolii, i.e., the middle-lower part of the brainstem and the pituitary gland (Farisco and Petrini, 2014). Therefore, the tumor did not fully or partially compromise the subject's capacity for consciousness and agency at the time of the crime.

5. Discussion

Aiming to contribute to the debate about the use of neuroscientific techniques in criminal procedures and more specifically about the role of experts – psychiatrists during these procedures, we collected criminal court cases from US and Europe, in which neuroimaging techniques were introduced.

Our main findings are the following:

Firstly, the two main reasons of the introduction of neuroscientific data in psychiatric expertise/testimony were to diagnose a specific psychiatric pathology or disease or/and to demonstrate brain damage.

Secondly, State experts disputed neuroimaging evidence in various ways, of which the main ones were the following: they questioned the capacity of neuroimaging techniques to diagnose a specific psychiatric pathology or brain injury, they disagreed over the interpretation of neuroimaging findings, they contested the adding value/relevance of brain imaging techniques, they disagreed on the relation between the brain disorder and violent behavior and on the extent of the defendant's responsibility.

As a general remark, it can be said that the use of neuroscience in court, in the way that it is presented by experts, raises the question of reframing mental disease as a brain disease. Reviewing the selected cases, it is evident that the notion of "psychiatric disease" is seen through different angles. Sometimes brain evidence is introduced by the experts in order to bolster and "objectify" diagnoses of conventional psychiatric diseases, such as schizophrenia or psychosis. In other cases, neuroimaging evidence is used in order to demonstrate brain damage without reference to a specific psychiatric condition, and elsewhere, the existence of brain damage is considered as a psychiatric condition itself, making the line between neurological and psychiatric disease uncertain.

Neurobiological information introduced through experts' testimony is used either to demonstrate some physical, organic base of a "conventional" psychiatric condition, or to make visible brain lesions, structural or functional, susceptible to have affected the capacity to reason and to control one's impulses, which correspond to the two basic legal criteria of criminal responsibility (cognitive and volitional). Thus, a procedure of "translation" from neuroscientific to legal language is taking place and neuroscientific experts' testimony is adapted to the legal jargon, in an effort to increase the validity of the legal arguments of the party who has called them.

Neuroscience is often presented by the defence as a scientific method, able to offer a precise diagnosis of the pathology in question. Judges often make the mistake of interpreting neuroimaging data as objective evidence of the existence of a mental illness, by assuming that the diagnosis of the illness can be made on the basis of brain images. This was the case in one of the Italian case, where the judge underlined the fundamental epistemological limitations of classic (clinical) psychiatric evaluations and concluded that neurological and genetic evidence could be a useful tool for establishing a diagnosis of mental pathology in a precise, objective and reliable manner.

However, although neuroimaging can today assist to some extent in the diagnosis of some neurological and psychiatric illnesses, few studies have been able to demonstrate a causal relationship between certain anomalies in brain structure or function and a particular mental illness. The scope of diagnosing a specific psychiatric illness with neuroimaging methods is very limited and contested (Mayberg, 2014; Lasden 2004; Farah, 2014; Adinoff and Devous, 2010). As observed in a number of cases, the effort of defence experts to prove the existence of a psychiatric pathology on the basis of a neuroimaging technique has been largely unsuccessful: the court was often convinced by state experts who denied the specific diagnosis on the basis of a brain scan or even argued for the dismissal of neuroimaging evidence as not complying with the Frye or Daubert standard criteria.

It should be noted that the existence of a psychiatric condition alone, with or without organic cause, does not per se impair or undermine the capacity to reason and control one's impulses. Moreover, these capacities are continuum concepts, impairment in these capacities is a matter of degree and there is disagreement about what degree of impairment is sufficient for mitigation or excuse. Even if a specific brain abnormality is associated with a mental illness, or correlated with a particular behavior, this observation is not sufficient to establish an excuse, since the criteria for ascribing criminal responsibility, or diminished criminal responsibility (in continental systems) are legal and defined within a specific legal framework. Thus, a neurobiological explanation of an offender's behavior, in the same way as any other causal explanation, is not in itself a reason for diminishing legal responsibility or excuse. At best, it can provide supplementary evidence which, when taken into consideration along with all the other aspects of each case, could help to ascertain whether there is an "excuse" in legal terms (Morse, 2011). What is therefore needed is a "translation" of the results of neuroscientific research and techniques presented to a court, to the legal language. This need for "translation" is considered by judges, as demonstrated for example, in Jackson v. Calderon, where the defendant had asked the court to grant him permission to provide PET scan evidence in order to prove his chronic PCP addiction. The judge confirmed the trial court's refusal, concluding that a PET scan could at best only establish that the defendant suffered from PCP brain induced abnormality. However what had to be proved specifically was that he was unable to premeditate or form a specific intent at the time of the shooting, which could not have been demonstrated by neuroimaging findings alone.

In addition, although the technical progress in the last decade has been spectacular, we are far from being able to apprehend all the complexity of brain function and neuroimaging techniques are still in an infant stage with serious technological limitations. Thus, the sensitivity of these methods remains limited (Farah, 2014; Aguirre, 2014), which is underlined by state experts on a regular basis.

In any case, it is generally observed that the very same neurobiological evidence is analyzed and interpreted in different - sometimes diametrically opposed - ways from the defence and prosecution experts. As expected, neuroscientific evidence is inevitably linked to a variety of judicial questions and the experts' testimony is strictly adapted to the legal context of the case. The defence strategy is crucial in the way in which neuroimaging evidence is going to be presented at court and shapes the way in which defence experts introduce and present this kind of evidence.

Conflicting interpretations of the same supposedly empirical evidence demonstrate the lack of unanimous consensus among neuroscientists regarding the specific role of certain areas of the brain and their impact on an accused's responsibility and decision making. Given the different roles of prosecution and defence in trials, it is understandable why the two parties would have different interpretations of the same data from imaging of a defendant's brain, and what it means for

the defendant's (degree of) capacity to control their behavior. The experts' disagreement is not about the imaging data as such, but about the way in which prosecution and defence interpret them, which is often biased and not value-neutral.

Conflicting testimony about the same empirical evidence goes against the hypothesis of neuroscience constituting "objective and hard evidence", able to reach solid, scientific and objective conclusions and shows that neuroimaging evidence is highly interpretative.

Interpretation is an essential stage in any scientific procedure. Imaging with fMRI in particular, is an inherently interpretive endeavor; fMRI measures changes in blood oxygenation level, but what is inferred is neural activity (Roskies, 2013; Aguirre, 2014). Processing of fMRI images is a "qualitative" analysis and the final images result from a series of processing steps and statistical analyses performed on the data. After collection of the biological data, in order for them to be further elaborated, a complex process takes place, requiring sophisticated statistical and mathematical tools. There is often lack of agreement about which statistics are best suited to analyzing the data. The intensive use of statistics in fMRI techniques can generate errors, and the statistics implemented are often a source of uncertainty (Vul et al., 2009). Devising statistical methods for analyzing imaging data is an ongoing area of research.

Even after the statistical analysis is performed, interpretation of the fMRI data may not be straightforward. As Jones and Shen (2012) point out, "there exists a long chain of inference from the fMRI scanner to the Courtroom. Functional brain imaging is not mind reading…While fMRI can accurately measure changes in blood flow and oxygen levels, interpreting those changes as reliable indicators of particular types of thought….requires a series of inferential steps that are not entirely straightforward".

It can be seen that data from neuroimaging experiments are derived from choices made by the neuroscientist at all stages of the experimentation, from the data collection protocol to the statistical methods used. It is the researchers who decide which information derived from the neuronal activity of the brain might be crucial for the assessment of capacity for rationality or control. Results of neuroscientific tests need to be interpreted by an expert, and the judge needs to be able to assess the validity and reliability of this interpretation. Neuroscientific evidence has a subjective dimension, precisely because it requires interpretation. This goes against the hypothesis of neuroimaging evidence being scientific and "objective" and suggests that, even with advances in brain imaging techniques, what the latter may tell us about the brain and its connection to thought and behavior will not just be empirical but at least partly normative.

Another issue which is central for the legal system is that of the individual meaning of the data collected. Neuro-psychological data is highly idiosyncratic in humans. fMRI techniques give results at group level, that is to say by averaging out subjects. Despite enormous progress in computing methods, aiming to minimize differences in brain anatomy across individuals, the wide variation in individual brain structure is a considerable obstacle to any attempt to apply the results obtained from a group of individuals to a single subject (Parens, 2014; Jones et al., 2013).

There are also limitations in what imaging can tell us about brain structure and function. Neuroimaging is often caricatured as a contemporary form of phrenology (Uttal, 2002). Often, results of neuroscientific studies are presented and interpreted in courts as evidence that certain acts or behaviors are the direct result of a dysfunction or lesion in a specific area of the brain, associated with a distinct psychological function. However, without denying the fact that the brain is made up of distinct regions, scientists agree that, even for the most basic brain functions, localization is imperfect. Brain regions are interconnected in a complex manner. Cognitive functions activate regions that are broadly distributed through the brain, and not a specific zone (Pustilnik, 2009). As Roskies (2013) points out, "although we know a lot about the gross neuroanatomy of the human brain, the detailed connectivity remains largely unknown, due to the formidable technical challenges that face researchers attempting to distinguish neural structure and connectivity at the level of neural circuits. The absence of a fine-grained picture of neural connectivity poses a major limitation on our ability to understand brain function".

Another issue which is raised in cases where neuroscientific evidence was introduced is the causal relation between neurobiological deficits and the manifestation of violent behavior, advanced by the defence as an argument to make their client appear less blameworthy. Inherent to this argument is the implication that their criminal behavior is the consequence of their biological construction, and thus, the crime is "not their fault" and they cannot be fully responsible. It seems that prosecution is rather attentive to this argument and to its appeal to juries and judges and responds to it in various ways, usually by directly contesting the existence of a causal relationship between brain abnormalities and criminal behavior.

For example in *State v Sapp*, though they did not contest the existence of some brain dysfunction of the defendant, prosecution experts offered another causal explanation, preferring to attribute the defendant's criminal behavior to *"an antisocial personality characterized by the lack of any restraints from societal prohibitions"*, rather than to *"brain abnormalities and neurological factors"*, as the defence had suggested.[42] Their interest in overthrowing the defence's argument about the relation between criminal conduct and brain dysfunction suggests that the prosecution is sensible to the appeal that this relationship can have to judges/jurors and fears that it influences the latter in favour of the defendant.

Many commentators have expressed concerns about the potential use of the link between brain abnormalities and criminal behavior by prosecution as an aggravating factor of dangerousness, especially in sentencing, based on the hypothesis of high risk of recidivism in subjects with brain damage (Farahany & Coleman, 2009; Barth, 2007, Snead, 2011; Gkotsi & Gasser, 2016). In reviewing cases, we did not come across such uses, although, as commented by Catley & Claydon (2016 p.18), *R v Hendy* suggests that evidence of neurocognitive defects may lead to an elevated view of the risk of harm posed by a defendant to society, as suggested by the imposition of a restriction order without limit of time.

As a general remark, it can be said that in most criminal cases where neuroimaging evidence has been used, appeals to neuroimaging are made to support mitigation in sentencing rather than excuse (Edersheim et al., 2012). This is mainly because of the uncertainty and ambiguity of the link between imaging and the brain, and between the brain and behavior. It is worth noting that neuroscientific evidence is not always successful and that judges are not always convinced by it, which goes against some recent research findings which suggests that imaging evidence may be unduly persuasive in spite of the lack of scientific support for its use to diagnose cognitive or behavioral impairments (Kulynych, 1997; McCabe & Castel, 2007; Mac Cabe, Castel & Rhodes, 2011; Weisberg et al., 2008a,b). The outcome of the cases – at least of the cases where we can assume that the outcome was influenced by neuroimaging testimony – varies, so that we cannot safely conclude that neuroscientific evidence is overly persuasive (also suggested in Michael, Newman, Vuorre, Cumming and Garry, 2013 and Schweitzer, Baker and Risko, 2013, though these studies are not referring to a legal context): in some cases, the judge was convinced by defence expert testimony, as was the case in one Italian case, where the judge explicitly relied on the neuroscientific expertise, considering it as "thoroughly and professionally" conducted, and predicted that *"the classic psychiatric approach, based on behavioural studies, is not going to be replaced by the neurosciences and genetics, but their integration into standard psychiatric expertise could enhance the objectivity of expert assessments"*.

[42] According to one of the defence experts, *Sapp* suffered from damage *in his temporal left lobe which caused sudden mood shifts and aggressive, violent destructive outbursts.*

However, in other cases, for example in the second Italian case, the judge carefully weighed all the evidence without giving excessive weight to neuroimaging evidence, considering that the latter was just one piece of evaluation taken into account in combination with other elements. The judge proved to be particularly attentive to other aspects of the case, evaluating the general behavior of the accused during the period before, during and after the crimes committed. The judge underlined that the accused was functioning normally without encountering any problems in other aspects of life and did not exhibit any altered perception of reality, which suggests that the defendant fully retained the ability to assess the illicit nature of his acts, and to make decisions based on this assessment.

6. Limitations

Several limitations must be mentioned. First of all, the number of studied cases included in the research does not allow for a generalization of the results. The latter is also limited by the fact that studied cases come from countries that belong to different legal systems. In addition, there is a disproportionate number of cases from the US, which also prevents any generalization of the results. Finally, the small number of cases found in Europe in particular limits the scope of our results concerning the introduction of neuroimaging data in relation the legal context of the case.

7. Conclusion

Neuroimaging evidence is already being introduced in courtrooms in the United States and around the world. In these procedures, the role of the experts is important, since their testimony is likely to influence the outcome of the case.

Even though respected as one of the major subspecialties of psychiatry, forensic psychiatry faces several criticisms and some controversies as long as it involves highly subjective decisions (Friend, 2003). These criticisms may also have to do with "stereotypes attached to malingered insanity defenses and the public's perception of insanity defense as a legal "loophole" by which criminals avoid or minimize punishment" (Ewing, 2008). In this context, rise of neuroscience in criminal courts raises hope for the construction of a more reliable criminal justice system, based on scientific and objective tools.

However, conflicting expert testimony and radically different interpretations of the same neuroscientific data suggest that the latter do not constitute hard evidence as opposed to soft data of psychiatry. On the contrary, neuroimaging evidence are as subjective, since they are open to interpretation by neuroscientists and are susceptible to being presented and interpreted by experts according to the legal side they represent.

Interpretation is an essential stage in any scientific procedure. With regards to the use of neuroimaging data in the criminal law, there are four levels of interpretation. First, neuroscientists must reach consensus on the significance of abnormal brain structure and function and how it might impair thought and behavior. This has to be framed in terms of a theory of the brain-mind relation and whether one accepts some version of reductionism or non-reductionism. Second, depending on what neuroscientists say about brain imaging, expert witnesses in forensic psychiatry testify on the defendant's capacity or incapacity to reason or control one's behavior. Third, prosecution and defence give their own interpretation of the connection between the brain data and the defendant's behavior. Finally, judges and juries consider all of this information and interpretation in making a judgment about conviction and sentencing.

Judges' decisions about whether neuroimaging data is legally relevant and admissible are normative decisions based on more than empirical evidence (Glannon, 2014).

Despite neuroscience's important assistance to the expert's task by offering a deeper understanding of the complex interplay between brain, mental state and behavior, there is a risk of returning to a reductionist and deterministic approach, if neuroscientific evidence is presented by the experts as the ultimate scientific and objective tool, able to prove a causal link between some structural or functional brain abnormality and the manifestation of criminal behavior.

Neuroscience data, however accurate and reliable they may become in the future, will only have meaning in the search for means to assess penal responsibility if they are contextualised and completed – or even confronted – with data collected on other levels of analysis, in particular psychological, sociological and economic (Ouiller, 2012). Advanced neuroimaging will better inform assessments of criminal responsibility but will not supplant or explain away the psychological and normative foundation of the criminal law (Glannon, 2014).

The introduction of neuroscientific evidence in legal proceedings potentially raises more responsibility for judges and courts: to epistemologically assess scientific knowledge (Farisco, 2014). Frequent conflicts between neuroimaging experts require the courts to deal with the resulting uncertainty.

As the law changes with technology, it will be necessary for legal professionals to be prepared for the new issues they may encounter in light of new developments in neuroscience. For this purpose, training of judges by neuroscientists within the context of special seminars and programs could prove very useful. Of course, the limitations of such an enterprise should be considered: increasing information about the brain will not provide a conclusive answer to the legally relevant question of the capacity to reason and control one's behavior. Any attempt to use neuroimaging information in a criminal trial comes across some conceptual limitations, having to do with the relation between brain and mind. The transition from brain states (described by neuroscience) and mental states (which are the focus of the law) remains an open metaphysical/philosophical question and sets an obstacle to any attempt to make legal assessments on the basis of the neurons. Neuroscience, as a science, can offer biological models of behaviors, while the assignment of responsibility is a normative issue.

However, as the use of neuroimaging techniques in criminal trials is increasing and as current knowledge among judges about the interpretation of neuroimaging findings is very limited, their training could be very useful: even if it would not provide a conclusive answer to the crucial legal issues at stake, it would be helpful in explaining and making it easier for them to understand the limitations of this kind of techniques and their interpretative nature. As judges may overestimate the importance of neurobiological deficits for the assessment of responsibility, or the prediction of criminal behavior, their training would aim to inform judges of the issues they may encounter in light of new developments in neuroscience and make them more vigilant as to the limitations, interpretation and meaning attributed to neuroscientific data.

Contributors

Georgia Martha Gkotsi, Valérie Moulin and Jacques Gasser conceived, planned and designed the study.

Georgia Martha Gkotsi wrote the manuscript with contributions from all authors.

All authors contributed and have approved the final manuscript.

Conflict of interest

No conflicts of interest to declare.

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References

Adinoff, B., & Devous, M. (2010). Scientifically unfounded claims in diagnosing and treating patients. *American Journal of Psychiatry*, *167*(5), 598.

Aguirre, G. K. (2014). Functional neuroimaging: Technical, logical, and social perspectives. *The Hastings Center Report*, *44*(s2), S8–18.

Barth, A. S. (2007). Double-edged sword: The role of neuroimaging in Federal Capital Sentencing. *American Journal of Law & Medicine*, *33*, 501.

Burns, J. M., & Swerdlow, R. H. (2003). Right orbitofrontal tumor with pedophilia symptom and constructional apraxia sign. *Archives of Neurology*, *60*(3), 437–440.

Catley, P., & Claydon, L. (2016). The use of neuroscientific evidence in the courtroom by those accused of criminal offenses in England and Wales. *Journal of Law and the Biosciences*, *2*(3), 510–549.

Chandler, J. A. (2016). The use of neuroscientific evidence in Canadian criminal proceedings. *Journal of Law and the Biosciences*, *2*(3), 550–579.

de Kogel, C. H., & Westgeest, E. J. M. C. (2016). Neuroscientific and behavioral genetic information in criminal cases in the Netherlands. *Journal of Law and the Biosciences*, *2*(3), 580–605.

Denno, D. W. (2015). Myth of the double-edged sword: An empirical study of neuroscience evidence in criminal cases. *The BCL Review*, *56*, 493.

Edersheim, J. G., Brendel, R. W., & Price, B. H. (2012). 10 Neuroimaging, Diminished Capacity and Mitigation. Neuroimaging in Forensic Psychiatry: From the Clinic to the Courtroom, 163.

Ewing, C. P. (2008). *Insanity: Murder, madness, and the law*. Oxford University Press.

Farah, M. J. (2014). Brain images, babies, and bathwater: Critiquing critiques of functional neuroimaging. *Hastings Cent Rep*, *44*(s2), S19–S30.

Farahany, N. (Ed.). (2009). *The impact of behavioral sciences on criminal law*. Oxford University Press.

Farahany, N. A., & Coleman, J. E., Jr. (2009). Genetics, neuroscience, and criminal responsibility. In N. A. Farahany (Ed.), *The impact of behavioral sciences on criminal law* (pp. 183–240). New York: Oxford University Press.

Farisco, M. (2014). In need of meta-scientific experts? *AJOB Neuroscience*, *5*(2), 50–52.

Farisco, M., & Petrini, C. (2014). On the stand. Another episode of neuroscience and law discussion from Italy. *Neuroethics*, *7*(2), 243–245.

Friend, A. (2003). Keeping criticism at bay: Suggestions for forensic psychiatry experts. *Journal of the American Academy of Psychiatry and the Law Online*, *31*(4), 406–412.

Gkotsi, G. M., & Gasser, J. (2016). Neuroscience in forensic psychiatry: From responsibility to dangerousness. *International Journal of Law and Psychiatry*, *46*, 58–67 May–June 2016.

Glannon, W. (2014). The limitations and potential of neuroimaging in the criminal law. *The Journal of Ethics*, *18*(2), 153–170.

Jones, O. D., & Shen, F. X. (2012). Law and neuroscience in the United States. In T. M. Spranger (Ed.), *International neurolaw* (pp. 349–380). Springer Berlin Heidelberg.

Jones, O. D., Wagner, A. D., Faigman, D. L., & Raichle, M. E. (2013). Neuroscientists in court. *Nature Reviews Neuroscience*, *14*(10), 730–736.

Kaufmann, P. M. (2013). Neuropsychologist experts and neurolaw: Cases, controversies, and admissibility challenges. *Behavioral Sciences & the Law*, *31*(6), 739–755.

Kulynych, J. (1997). Psychiatric neuroimaging evidence: A high-tech crystal ball? *Stanford Law Review*, *49*(5), 1249–1270.

Lasden, M. (2004). Mr Chiesa's brain–can high-tech scans prove that criminal acts are the result of a damaged brain. *California Lawyer*, 26–30.

Mayberg, H. S. (2014). Neuroimaging and psychiatry: The long road from bench to bedside. *The Hastings Center Report*, *44*(s2), S31–S36.

McCabe, D. P., & Castel, A. D. (2007). Seeing is believing: The effect of brain images on judgments of scientific reasoning. *Cognition*, *107*(1), 343–352.

McCabe, D. P., Castel, A. D., & Rhodes, M. G. (2011). The influence of fMRI lie detection evidence on juror decision-making. *Behavioral Sciences & the Law*, *29*(4), 566–577.

Michael, R. B., Newman, E. J., Vuorre, M., Cumming, G., & Garry, M. (2013). On the (non) persuasive power of a brain image. *Psychonomic Bulletin & Review*, *20*(4), 720–725.

Morse, S. (2011). Lost in translation?: An essay on law and neuroscience. In M. Freeman (Ed.), *Law and neuroscience: Current legal issues. Vol. 13.*. USA: Oxford University Press.

Myers, L. W. (1965). Battle of the experts: A new approach to an old problem in medical testimony. *The Nebrasaka Law Review*, *44*, 539.

Nadelhoffer, T., & Sinnott-Armstrong, W. (2012). Neurolaw and neuroprediction: Potential promises and perils. *Philosophy Compass*, *7*(9), 631–642.

Neufeld, P., & Scheck, B. (2010). Making forensic science more scientific. *Nature*, *464*(7287), 351.

Ouiller, O. (2012). Le neurodroit en perspective. In O. Ouiller (Ed.), *Le cerveau et la loi–analyse de l'émergence du neurodroit* (pp. 169–188). Paris: Centre d'analyse stratégique [Document de travail no 2012–07. Available from: http://archives.strategie.gouv.fr/cas/system/files/2012-09-11-neurodroit-na2820.pdf visited on 10/09/2016.

Parens, E. (2014). Living with the ancient puzzle. *Hastings Center Report*, *44*(s2), S50–S52.

Pustilnik, A. C. (2009). Violence on the brain: a critique of neuroscience in criminal law. *Wake Forest Law Review*, *44*, 183–238.

Roskies, A. L. (2013). Neuroscience basics. In S. J. Morse, & A. L. Roskies (Eds.), *A primer on criminal law and neuroscience: A Contribution of the Law and Neuroscience Project, Supported by the MacArthur Foundation* (pp. 2013). Oxford University Press.

Schweitzer, N. J., Baker, D. A., & Risko, E. F. (2013). Fooled by the brain: Re-examining the influence of neuroimages. *Cognition*, *129*(3), 501–511.

Silva, J. A. (2009). Forensic psychiatry, neuroscience, and the law. *Journal of the American Academy of Psychiatry and the Law Online*, *37*(4), 489–502.

Simpson, J. R. (2012). *Neuroimaging in forensic psychiatry: From the clinic to the courtroom*. Chichester, West Sussex, England: Wiley-Blackwell.

Sirgiovanni, E., Corbellini, G., & Caporale, C. (2016). A recap on Italian neurolaw: Epistemological and ethical issues. *Mind & Society*, 1–19.

Snead, O. C. (2011). Cognitive neuroscience and the future of punishment. In J. Rosen, & B. Wittes (Eds.), *Constitution 3.0: Freedom and technological change* (pp. 130–155). Brookings Press.

Uttal, W. R. (2002). Précis of the new phrenology: The limits of localizing cognitive processes in the brain. *Brain and Mind*, *3*(2), 221–228.

Vul, E., Harris, C., Winkielman, P., & Pashler, H. (2009). Puzzlingly high correlations in fMRI studies of emotion, personality, and social cognition. *Perspectives on psychological science*, *4*(3), 274–290.

Weisberg, D. S., Keil, F. C., Goodstein, J., Rawson, E., & Gray, J. R. (2008a). The seductive allure of neuroscience explanations. *Journal of Cognitive Neuroscience*, *20*, 470–477.

Weisberg, D. S., Keil, F. C., Goodstein, J., Rawson, E., & Gray, J. R. (2008b). The seductive allure of neuroscience explanations. *Journal of Cognitive Neuroscience*, *20*(3), 470–477. https://doi.org/10.1162/jocn.2008.20040.

Witzel, J. (2012). Implications of neuroimaging for dangerousness assessment. In J. R. Simpson (Ed.), *Neuroimaging in forensic psychiatry: From the clinic to the courtroom* (pp. 195–200). Chichester, West Sussex, England: Wiley-Blackwell.

Witzel, J., Walter, M., Bogerts, B., & Northoff, G. (2008). *Neurophilosophical perspectives of neuroimaging in forensic psychiatry*.