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The Use of Neuroscientific Discoveries in Criminal and Civil Evidence Law

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Abstract The problem of objectification in criminal and civil evidence law is the basis of present work. Neuroscientific discoveries should be taken into account in evidentiary procedures when objectifying subjective facts. The first neuroscientific steps in objectifying pain and other subjective facts have already been made. The author outpoints certain limitations in the field of incorporation of neuroscientific discoveries into judicial procedures. He argues that some neuroscientific discoveries are already suitable for evidentiary purposes and their number will gradually increase. Neuroscience is looking forward to a gradual improvement of neuroimaging technologies that will increase the number of (reliable) discoveries applicable in evidence law. Neuroscientific discoveries are going to become an important part in objectification of subjective facts in criminal and civil procedures.

Keywords: • Neurolaw • Evidence Law • Neuroscience • Evidential Value • Subjective Facts • »Objectification of Subjective« •

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1 Introduction

A complete formulation of the *praemissa minor*[1] is necessary to ensure legality in judicial procedures. The court is obliged to ascertain all facts that are legally relevant for evidentiary purposes (Pavčnik, 2007). Those facts are essential to evidence law, because only facts with legal consequences are relevant for judicial decisions. Therefore, the ascertainment of legally relevant facts in one of the most important acts in judicial procedures.

Legal scholars distinguish between different types of facts.[2] Generally speaking, facts are phenomena observable and perceivable in our environment. They can be external or internal (spatial component) and belong to past, present or future circumstances (time component). External (objective) facts are part of the outside world, while the existence of internal (subjective) facts depends on subjective experiences of individuals. The latter represent circumstances that are not manifested externally, therefore their perception by external »observers« is only indirect (Dežman et al., 2003, see also Rechberger & Simotta, 2003). Facts are distinguishable also by their time component. At the moment of their ascertainment present facts *exist*, past facts *do not longer exist* and future facts *do not yet exist.* It is indisputable that existing facts are easier to ascertain, as their observation and perception takes place in the present. On the other hand, ascertaining past and future facts requires much more effort. Ascertaining past facts requires an analysis and evaluation of events and human actions that have already taken place, while discerning future facts requires anticipation skills.

The same applies to objective and subjective facts. Ascertaining subjective facts is more demanding than the ascertainment of objective facts, because they are not manifested in the external world.[3] Therefore, the possibility of their observation and perception is heavily limited. Consequently, the importance of subjective facts can significantly decrease or even worse, they can be overlooked in judicial decision making (Kolber, 2014). However, the application of legal syllogism requires the ascertainment of all legally relevant facts – objective, subjective, past, present and future facts. Otherwise, the functioning of the legal system would be jeopardized. It is therefore important that all legally relevant facts are ascertained, but the question arises, how to achieve a reliable objectification of those that are subjective? The existence (or non-existence) of subjective facts depends on the subjective experiences of individuals that are empirically inaccessible to external »observers«. For this reason, the courts are caught in a vicious cycle. On one side, they are obliged to ascertain all legally relevant facts, and on the other, they are faced with

[1] *Praemissa minor* as the lower premise of the legal syllogism.
[2] Positive and negative facts, external (objective) and internal (subjective) facts, past, present and future facts, etc.
[3] Under the term subjective facts, we understand all facts that are not objective – facts that are not manifested in the external world and therefore can not be objectively perceived.

the complexity of ascertaining subjective facts. The truth about the existence of subjective facts is known only by those who stand in a special subjective-empirical relationship with them. The court's persuasion on the actual existence of a subjective fact is therefore only an approximation of the truth, since in the court lacks the capacity to have direct insight into the subjective experiences of individuals. A higher level of reliability in ascertaining subjective facts could be achieved if science succeeded in »breaking into the human interior«. The insight into the subjective experiences of individuals would create the possibility of more accurate conclusions about the existence of subjective facts.

2 Neurolaw – the Interdisciplinary Field of Neuroscience and Law

At first glance, it would appear that neuroscience and law do not have much in common. The former is interested in the nervous system, with an emphasis on the human brain, while the latter focuses on social relations. However, facts regarding individuals and their behaviour, cognition and mental states are equally important for both. Since their judicial ascertainment (often) depends on various scientific discoveries, the question arises: can neuroscientific discoveries contribute to more reliable objectification of legally relevant subjective facts? An answer to that question can be found in the interdisciplinary field of neurolaw, where neuroscientific discoveries intertwine with legal problems.

2.1 The History of Neurolaw

The term neuroscience at present is considered as a general term for brain research (»the science of the brain«). Pustilnik (2009), a Professor at the University of Maryland School of Law, has stated that »(criminal) law and neuroscience have been engaged in an episodic and ill-fated love affair for over two hundred years«. But the history of neurolaw goes even further back in time. The earliest records of brain injuries originate from 5000 BC in ancient Egypt. Younger, but significantly more important, is the Edwin Smith (Surgical) Papyrus from 1700 BC. It contains hieroglyphs, which represent the earliest written mention of the brain, and describes brain damages, their connection to different neurological symptoms, the cerebral cortex and many other details that justify its reputation as the most important empirical practicum of ancient Egypt. Not surprisingly, the oldest records on the existence of medicine and law originate from the same period. There is no doubt that Imhotep, the Grand Vizier of King Zozer, significantly contributed to the emergence of the interdisciplinary field of medicine and law. The (administrative) fields of medicine and judiciary were united in his persona, since he was the chief physician and chief justice, which is why he is considered to be the pioneer of the interdisciplinary field of medicine and law (Smith, 1954). When reviewing the above-mentioned medical records, it can be concluded that the brain occupied an important place in the medicine of the ancient Egyptians. Therefore, it is very likely that they also dealt with the interweaving of neuroscience and law, which could have resulted in the emergence of neurolaw.

Although there is no reliable evidence that medical discoveries were used in (legal) evidentiary purposes in ancient Greece, there is no doubt that the interaction of medicine and law actually occurred. It is well known that Hippocrates and his contemporaries discussed a number of questions concerning medicine and law (Wecht, 2005). Because of the position enjoyed by doctors (and philosophers) in ancient Greece, their opinions and discoveries were certainly used in legal proceedings (Smith, 1954). Given that doctors (and philosophers) also dealt with brain issues, for example Alcmaeon with the sensory perception center, Hippocrates with epilepsy and Plato with the concept of memory (Gross, in: Adelman, 1987, see also Wickens, 2015), it is very likely that neuroscientific discoveries were used to solve legal problems too. Due to the high level of scientific knowledge achieved by the Greeks, it makes sense to believe that progress had also been made in the field of neurolaw.

It is well known that Roman law is one of the most magnificent and complete legal systems of Antiquity. While not occurring in the initial period of the Roman Empire, medical discoveries gradually made their way into legal proceedings. At the time of Justinian, medicine became legally regulated. The conditions for performing medical practice, as well as the areas of (official) medicine and the number of doctors per population were determined by law. The *Codex Iustinianus* stipulated that medical experts were required to be impartial assistants of the court (*amicus curiae*) with special knowledge (Wecht, 2005). At that time, progress had been made in the field of forensic medicine, as the *Codex* prescribed obligatory involvement of medical experts in some court proceedings (Smith, 1954). There is no doubt that development has occurred in the areas of forensic medicine and medical law, but there was little progress in the area of neurolaw. Brain research in ancient Rome after all, with the exception of Galen, was not intense. It can be assumed that individual neuroscientific discoveries were used in legal proceedings, such as the connection between external forces and brain injuries that resulted in disability or death, but there is no hard evidence to support this assumption. We therefore conclude that neurolaw in ancient Rome did not develop noticeably. After all, it is not possible to talk about interdisciplinarity between neuroscience and law not even after Galen's death, when his ideas have become dogmatic. Since nobody questioned those ideas over the next 1500 years and (consequently) neuroscience could not develop, it is not surprising that the European Middle Ages did not contribute to the development of neurolaw (Gross, in: Adelman, 1987).

The Renaissance of European (neuro)science took place in the 16th century. The *De Humani corporis Fabrica* by Andreas Vesalius was published in 1543, and had a great impact on the (dogmatic) medicine of that time. In about the same period, legal rules regulating forensic medicine were adopted. The *Constitutio Criminalis*

Carolina, the Criminal Code of Charles V., for example, prescribed obligatory involvement of medical experts in criminal proceedings when deciding on murders, poisonings and other criminal offenses, resulting in bodily injuries (Smith, 1954). In France, a number of regulations were adopted between 1570 and 1692, which encouraged the development of the interdisciplinary field of medicine and law. The *De Relationes Medicorum* by Fortunato Fedela and the *Quaestiones Medicina-Legales* by Paola Zacchia, the *magnum opus* of that era, dealt with a number of medical questions with a significant impact on law (Wecht, 2005). Gradually, the first departments on forensic medicine and medical law were established in Germany and France (Smith, 1954).

Concurrently, neurolegal development was taking place. Zacchia, for example, argued that it was necessary to involve medical experts in legal proceedings concerning mental incompetence of individuals, since mental disorders were (correctly) understood merely as a result of brain abnormalities (Mellyn, 2014). The interdisciplinary field of neuroscience and law therefore had begun to awaken from a long sleep. Brain research gradually intensified in the 18th century, which also deepened the neurolegal discourse.

Up until this point, the development of neurolaw was substantiated (mainly) on the basis of the development of the interdisciplinary field of medicine and law. Direct evidence on its existence appeared relatively late, which might explain the background of Pustnilnik's statement about the (only) »two centuries lasting love affair of neuroscience and law«. The first interdisciplinary conference on neurolaw took place in 1873 in New York, where physicians and lawyers gathered to establish a dialogue between the professions to improve the applicability of medical discoveries (on the brain) in law. The topics discussed were highly similar to contemporary neurolegal problems, such as the question of mental (in)competence and legal responsibility (Shen, 2016, see also Tighe, 1986). Although the number of associations dealing with related questions increased rapidly, the initial enthusiasm did not last long. Most scientific discoveries were rejected by lawyers as irrelevant, therefore the theories about the neurological (biological) basis of mental incompetence failed to make their way into legal proceedings. It was difficult to prove causality (or at least correlation) between abnormal brain states and unlawful acts, without the necessary tools for examining the brain. Many 19th century theories on the neurological basis of mental life remained on the level of hypotheses without greater legal significance, mostly because they raised more questions than offered answers to the problem of distinguishing *pathological* from *normal* (Shen, 2016).

From the abovementioned moment on, the interdisciplinary field of neuroscience and law started to develop at an accelerated pace. After the foundations were established, three major moments took place in the history of neurolaw: (1) the introduction of electroencephalography (EEG) evidence into the legal system in the mid-twentieth century, (2) the use of psychosurgery for violence prevention in the 1960s and 1970s, and, most recently, (3) the development of neurolaw in personal injury litigation in the late 1980s and 1990s (Shen, 2016). Parallel to these key developments, modern neurolaw has started to emerge.

2.2 Modern Neurolaw

We have already defined neurolaw as the interdisciplinary field of neuroscience and law. But neuroscience is not only a general term for brain research (»the science of the brain«). Depending on its approach, it can be either traditional or modern. Traditional neuroscience is based on particular brain research, focusing on the needs and specificities of individual (traditional) scientific disciplines. On the other hand, modern neuroscience is defined by interdisciplinary brain research and the use of (modern) neuroimaging technologies (Shen, 2016). Considering the abovementioned distinction, we can differentiate between traditional and modern neurolaw as well. The former investigates the applicability of traditional neuroscientific discoveries into law, while the latter the applicability of modern ones. Therefore, we can talk about modern neurolaw only after the emergence of interdisciplinary brain research and the invention of (modern) neuroimaging technologies.

Interdisciplinary brain research emerged in the second half of the 20th century, when (neuro)scientists formulated the revolutionary idea that interdisciplinary, international and team work could significantly improve understanding the brain (Cowan et al., 2000, see also Bear et al., 2016). The first interdisciplinary and interuniversity program for brain research – the Neuroscience Research Program (NRP) - was created in 1962, bringing together (neuro)scientists in the fields of chemistry, physics, immunology, genetics and molecular biology (Cowan et al., 2000). The invention of (modern) neuroimaging technologies, such as the computed tomography (CT), positron emission tomography (PET), (functional) magnetic resonance imaging ((f)MRI) etc., took place in about the same period. These ground-breaking innovations enriched our knowledge with new (modern) neuroscientific discoveries and paved the way for the emergence of modern neurolaw.

The discoveries of modern neuroscience were first applied in criminal and eventually in civil law (Shen, 2017). Opinions on the importance of modern neurolaw vary, however (Nadelhoffer & Nahmias, 2011). Morse (1982), for example, is convinced that the use of (modern) neuroscience is yet another of many failed attempts to substantiate the basis of criminal liability, while Goodenough (2001) is convinced that future neuroscientific discoveries will require society to reexamine legal concepts in their foundations. An intermediate position was accepted by Greene and Cohen (2004), authors of the famous sentence (article title): »*For the Law, Neuroscience Changes Nothing and Everything*«. They believe that neuroscientific discoveries will have a significant impact on the legal system, but will not revolutionize the law as we know it today (Nadelhoffer & Nahmias, 2011).

3 Neuroscientific Discoveries in Evidence Law

Discoveries of modern neuroscience today play a significant role in both criminal and civil evidence law. Most Criminal Codes stipulate that mentally incompetent offenders are not criminally responsible for their actions.[4] Mental incompetence is a condition in which a person is not aware of his actions or can not control his behavior because of mental disorder or mental underdevelopment. Only offenders who understood the meaning of their action and had control over their behavior can be found guilty in criminal procedures. However, due to mental disorders or mental underdevelopment, many of them are not capable of that. The question arises as to whether it is possible to take into account neurobiological causes as a reason for exculpating one from a crime (Zgaga, in: Salecl et al., 2015).

Mental disorders are defined by various combinations of pathological changes of thoughts, emotions, perception, behavior and disabilities of cognition and memory. They are a manifestation of pathologically changed behavioral, psychological and biological functions of individuals.[5] There is no doubt that many forms of mental disorders, recognized by legal theory and case law, stem from neurobiological causes (Bavcon et al., 2009). Therefore, the answer to the question can only be affirmative. Neurobiological causes can be understood as legally relevant reasons for excusing guilt.

The aforementioned mental disorders cannot be ascertained by the court without the involvement of medical experts – psychiatrists, who are undoubtedly most often in relationship with persons with mental disorders (Plesničar, 2016). Since they are considered as subjective facts, a higher level of reliability in their ascertainment could be achieved if science succeeded to »break into the human interior«. And this is the point where neuroscience arises. Neuroimaging methods are capable of ascertaining subjective facts more reliable, including facts regarding mental disorders and mental underdevelopment. With the help of (f)MRI and other neuroimaging methods, neuroscientists can detect a myriad of functional and structural changes in the brain that cause mental abnormalities. Therefore, the courts should take advantage of neuroscientific discoveries when deciding on the question of mental (in)competence. On the other hand, it is true that not all functional and structural brain changes lead to mental incompetence. For this reason, if neurobiological causes of deviant behavior are ascertained, the court may apply the doctrine of substantially diminished mental competence and impose a reduced punishment.[6]

[4] For instance, Article 29 of the Slovenian Criminal Code.
[5] Higher Court in Ljubljana, [2011] 16 April, VSL I Kp 78/2008.
[6] For instance, Article 29 of the Slovenian Criminal Code.

Questions regarding mental conditions are equally relevant to civil evidence law. For example, the problem of children's capacity for reasoning arises often in civil procedures. The second paragraph of Article 137 of the Slovenian Obligations Code, for example, stipulates that minors aged seven and over but under fourteen shall not be liable for damage, unless it is shown that they were capable of accounting for their actions when the damage was inflicted. When applying this article, the courts could take advantage of the established neuroscientific discovery that individual brain regions do not develop at the same time (De Kogel et al., 2013). For example, it is known that while the amygdala already is developing in early adolescence, the development of the prefrontal cortex takes more time and is not completely developed until a human reaches the mid-twenties. Those two brain regions have different functions. While the amigdala is »responsible« for rewarding and emotions, the prefrontal cortex is »responsible« for reasoning, decision-making and impulsivity control. Excessive emotional responses, impulsivity and unreasonable risk-taking on the part of minors therefore could be explained as resulting from the imbalance between the developed amygdala and the underdeveloped prefrontal cortex (Harris et al., 2011). If we attribute the act of the minor, who caused the damage, to the alleged imbalance, it can be concluded that the minor cannot be held legally responsible for his or her actions. The special conclusion has been derived from the general discovery (upper premise) that the underdeveloped prefrontal cortex is the reason why minors lack the mental capacity for complete reasoning. If the upper premise is correct, then the general discovery applies to that particular minor too. In the upper case an existing neuroscientific discovery was applied to ascertain civil liability (statistical method). The method used is based on generalization, i.e. deductive reasoning on the developmental level of children's brains in relation to the general population, which ignores the differences between individuals. Therefore, it may happen that the developmental level of a particular brain does not correspond to the brain development of the general population. The abovementioned danger can be avoided by applying one of the neuroimaging methods to observe the brain development of that particular minor (clinical method). Since the clinical method ensures a higher degree of reliability, there would be no need for deductive reasoning, i.e. the use of the statistical method (Harris et al., 2011).

The statistical and clinical methods are already being used in judicial procedures. In one of the cases, a Dutch court was appointing provisional supervision to a child who refused a blood transfusion due to religious reasons. The minor showed high loyalty to his (exaggeratedly) religious family, that made him unable to distinguish between his own opinion and the opinion of his parents. The court concluded that the minor was not capable of making his own decisions, since his brain was not sufficiently developed. The inability to make long-term decisions is a distinctive characteristic of the developing brain of a minor. On the basis of that conclusion, the Dutch court appointed a provisional supervisor to the child. The court also decided, on the basis of the existing neuroscientific discovery, that minors are mentally incapable of making long-term decisions due to their underdeveloped prefrontal cortex.[7] In a different Dutch case, a 91-year-old senior claimed that his ability to consent to marriage was not impaired, even though he suffered from dementia. The man relied upon the opinion of a medical geriatric expert who opined that the man's capacity for reasoning was not adversely affected by his dementia (and age) and that there was no impediment to the conclusion of the marriage. On the other hand, the man's children referred to medical documentation created on the basis of an MRI and clinical and neuropsychological assessment. This medical workup suggested that the senior was suffering from the initial signs of dementia. Nevertheless, the court accepted his claim and concluded that his capacity for reasoning was not adversely affected by the dementia. The problem in this case was that, despite the neuroscientific proofs of dementia, the court nevertheless rested its decision exclusively on the basis of external factors, i.e. the geriatric opinion and the court's perception at the main hearing.[8] In a third case, the plaintiff disputed the validity of his registered partnership. He referred to an expert opinion, which included neuropsychological, clinical and radiological diagnoses. It was ascertained that the plaintiff suffered from Alzheimer's disease and was not able to express his true will at the time of the registration. Despite the defendant's objection that the plaintiff's capacity for reasoning could be ascertained only with a medical opinion that was contemporaneous with the time when the partnership was registred, the court followed his claim and annulled the partnership.[9] The court's decision was based on the clinical method, taking into account the expert opinion that was created exclusively and specifically for the case before the court (De Kogel et al., 2013).

The application of neuroscientific discoveries is becoming increasingly common in cases dealing with substantially diminished mental competence. In the recent case of John McCluskey, who was charged with double murder, neuroscientific discoveries (PET and MRI) were presented by the defendant's attorneys. The evidence showed structural and functional abnormalities in his brain, i.e. 10 areas with below average brain activity and 17 areas where the functioning of the brain was hyperactive. McCluskey's attorneys argued that irregularities in his amygdala caused misinterpretations of environmental signals, which in turn triggered a "false alarm", wherein his unbridled primitive emotional impulses could not be be prevented due to irregularities in his prefrontal cortex. As a result of the above-described combination of irregularities, McCluskey, it was argued, could not fully understand the meaning of his action and control his behavior. Since the jury could not reach unanimity to impose the death penalty, the court reduced the punishment and sentenced him to life imprisonment (Hafner, in: Salecl et al., 2015). The McCluskey case demonstrates how neuroscientific discoveries can help to mitigate the punishment due to substantially diminished mental competence.

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[7] District Court Amsterdam [2010] 12 March, LJN BL9136.
[8] District Court Dordrecht [2007] 25 October, LJN BB6577.
[9] District Court Den Haag [2011] 21 February, LJN BP7696.

European courts recognize the field of neurolaw in criminal cases as well, applying various neuroscientific discoveries to particular facts patterns that have come before them. Italian courts, for example, imposed reduced punishments in cases of murders and pedophilia. The murderer justified his act with neuroscientific evidence showing brain abnormalities, while the pedophile relied upon images showing a tumor in his brain (Hafner, in: Salecl et al., 2015). However, the use of neuroscientific discoveries in evidence law has been used in other areas aside from the criminal law context to provide support for imposing reduced punishments.

The principle of material truth requires a complete and truthful ascertainment of legally relevant facts.[10] But »the truth« is not always objectively ascertainable. In the case of subjective facts, the truth is known only by those who are in a special subjective-empirical relationship with it. The existence (or non-existence) of subjective facts depends on the subjective experience of individuals that are empirically inaccessible to the external »observers«. The judicial persuasion on the existence of subjective facts is therefore only an approximation to the truth, due to the courts' inability to have direct insight into the subjective experiences of individuals. A higher level of reliability in ascertaining subjective facts could be achieved if science succeeded to »break into the human interior«. The insight into the subjective experiences of individuals would unlock the possibility of gaining more accurate conclusions about the subjectively »colored« truth. Among neuroscientists, the different neurological background of lying and truth-telling is more or less undisputable (Spence & Kaylor-Hughes, 2008). Research has shown, for example, that lying increases the activity of the prefrontal cortex, i.e. the brain region »responsible« for cognitive effort and selecting among alternative options (Bles & Haynes, 2008). Neuroscientists believe that activation of the prefrontal cortex is associated with both the suppression of truth and the formation of lies (Harris et al., 2011). The latter increases the concentration and creativity among individuals, since the creation of false stories requires more mental effort than telling the truth (Goodenough & Tucker, 2010). This neuroscientific discovery is already being used in commercial purposes (Hafner, in: Salecl et al., 2015). By way of example, some companies have claimed that on the basis of observation of brain activity (fMRI) they can distinguish between lying and truth-telling.[11] So the question arises: can the use of neuroscientific discoveries improve the chances of ascertaining the truth in evidentiary procedures? There is, unfortunately, no clear answer to this question. The potential of neuroscientific lie detection rests upon detecting brain regions that activate during lying. But an increased activity in a particular brain region, while providing some evidentiary support, does not necessarily lead to the firm and unequivocal conclusion that the person observed is lying. Due to the complexity of the human brain and the cognitive background of

[10] For instance, Article 17 of the Slovenian Criminal Procedure Act.
[11] Commercial companies such as Cephos in No Lie MRI.

lying, there are still many questions to be answered (Harris et al., 2011). After all, it can not be overlooked that neuroscientific lie detectors can pressure the free will and interfere on privacy. Therefore, we can make the following conclusion: although an increased activity of the prefrontal cortex can indicate that a person is lying, but the legal applicability of neuroscientific lie detectors, since there are many variables that exist, depends on the specific circumstances in any given case.

The abovementioned method of lie detecting is closely related to the method of brain fingerprinting. Neuroscientists have been able to determine what an individual sees – from simple characters and letters to complex images. Building upon this knowledge, neuroscientists have been able to search for memory traces in the brain (Faulkes, 2011, see also Hafner, in: Salecl et al., 2015). Memories are stored in different brain regions and (most likely) depend on neuroplasticity, also known as brain or neural plasticity, i.e. the ability of the brain to change throughout an individual's life. Although the mechanisms allowing humans to recall memories are not as of yet well-understood, neuroimaging technologies have the capacity to locate those regions responsible for storing memory (Mohorko et al., 2014). Some neuroscientists are convinced that monitoring the electrical signals, which are emitted by the brain when already known stimuli is detected, can determine whether an individual is familiar with particular information or not. This method, which allegedly provides up to 99.99% reliability in brain fingerprinting, received a number of criticisms by the neuroscientific community. The majority of scientists are convinced that the reliability of brain fingerprinting has been significantly overstated by its proponents. However, because this method is protected under intellectual property laws, it is difficult to fully assess its scientific reliability (Hafner, in: Salecl et al., 2015). Despite the criticism, the method of brain fingerprinting has already been used in evidential procedures. In the case of Harrington vs. Iowa, neuroscientific evidence showed that the memory traces in the defendant's brain did not match with the place of the crime, but did match with the location of the alleged alibi. In the renewed procedure, the discovery was presented to the only witness of the (alleged) crime, who admitted giving false testimony in the first procedure. Due to lack of evidence, Harrington was found not guilty (Mohorko et al., 2014). The Harrington case demonstrates that neuroscientifically unreliable methods are not necessarily irrelevant to evidence law. This is especially true when they are proposed by the defense in order to prove the defendant's innocence. However, pressure on free will and interference on privacy interests are equally present when applying this method. Therefore, the limitations and caveats discussed above have to be considered with the same degree of care.

Neuroscientific discoveries can also be useful in ascertaining and confirming the existence of pain. Pain is an unpleasant (sensory or emotional) feeling that is associated with actual or potential tissue damage (Merskey et al., 1994). Since the majority of pain signals are processed in the brain (Kolber, 2007), neuroscientists have reached the conclusion that the existence of pain can be detected by observing cerebral activity (Baliki et al., 2010). This finding is supported by a recent study from Stanford University, in which the authors observed the activity of the brain during thermal exposure (Brown et al., 2011). Their research revealed that cerebral activity in stimulated circumstances is different from activity when an individual is not exposed to thermal stimulation. In the next phase of their work, eight new subjects were included in the research. This time, the scientists relied on the results of the previous phase of their study and determined the (non)existence of thermal stimulation on the basis of observing their subjects' brain activity. This was achieved with an eighty percent success rate (Kolber, 2014). In another research study, a neuroscientist succeeded in identifying people suffering from chronic back pain. The study involved individuals with and without pain, whose backs were exposed to painful thermal stimulation. Findings from this study showed that pain perception and related cortical activation patterns were similar in the two groups. However, nucleus accumbens activity differentiated the groups at a very high accuracy, exhibiting phasic and tonic responses with distinct properties (Baliki et al., 2010). The nucleus accumbens is a region in the hypothalamus that plays an important role in the cognitive processing of pleasure and rewarding. In individuals without chronic pain, the cessation of thermal stimulation affected with relief and rewardingly, as the acute heat pain stopped. Therefore, the blood oxygen-level dependent (BOLD) signal in that region was positive. On the other hand, in individuals with chronic back pain, the BOLD signal was negative, as the thermal stimulation initially stopped their (chronic) pain, which affected with relief and rewardingly. However, after the stimulation ceased, their back pain returned (Gazzaniga et al., 2010).

The above-presented neuroscientific objectification of pain is very useful in (civil) evidence law. The (non)existence of pain is a typical subjective fact. We have already concluded that we could achieve an increased level of reliability in ascertaining subjective facts if science succeeded to »break into the human interior«. The insight into subjective feelings of individuals would open the possibility of more accurate conclusions about the (non)existence of pain and other subjective facts.

Neuroscientific discoveries in evidence law can contribute to a more reliable objectification of subjective facts. By observing brain activity, facts related to the implied consent of victims, intention and negligence, mental health, legal capacity and many more legally relevant facts could be more reliably ascertained in both criminal and civil evidence law (Eggen & Laury, 2012, see also De Kogel et al., 2013).

4 Conclusion – the Future of Neurolaw

It is impossible to know what the future holds. We can assume that many neurolegal questions will remain unanswered (in the near future). The development of neurolaw will require advancements in the fields of both neuroscience and the law (Shen, 2017). After all, the treasure trove of knowledge about the human brain is far from being filled (Marcus et al., 2015). Advancements in our knowledge is slow (mainly) due to the complexity of the human brain and limitations of neuroimaging. But despite the limitations of (modern) neuroscience, the situation is far from alarming and in fact there is much to be encouraged by. As this paper has shown, over the past few decades, our knowledge about the human brain has increased more than in the rest of the neuroscientific history. The exponential development of (neuro)science coupled with the large number of scientists involved in brain research are the main factors driving the reasonable expectation that the further development of neuroscience will be even more intense (Wickens, 2015). We are looking forward to a gradual improvement of neuroimaging technologies that will increase the number of (reliable) neuroscientific discoveries applicable in criminal and civil evidence law.

However, the further development of neurolaw will require additional (financial) investors, especially from the private sector, which is currently focused on neurotechnology. Therefore, it will be necessary to educate those investors about the potential of the interdisciplinary field of neuroscience and law (Shen, 2017). Additionally, it will be necessary to promote interdisciplinary education for students so that they might acquire both neuroscientific and legal knowledge. Most students already have the opportunity to upgrade their basic knowledge (e.g. within elective courses), while particular universities offer the possibility of interdisciplinary study on a higher degree. For example, the University of Wisconsin has been offering an interdisciplinary study program of Neuroscience, public policy and law since 2005,[12] while the University of Pennsylvania offers law students the possibility to obtain a certificate in social, cognitive and affective neuroscience.[13] The number of such and similar study programs is not high, but it is expected that their number will gradually increase. Although neurolaw is important for students (and academics), it is even more important for adults who have already completed their formal education. After all, neuroscientists and lawyers to whom those interdisciplinary study programs are no longer available should have the most knowledge in the field of neurolaw. Therefore, it is critical that lawyers get fully acquainted with neuroscientific discoveries that are applicable in law, while neuroscientists will have to ascertain the legal impact of their research. Anyone working in the field of neurolaw will have to choose the primary and secondary field of his work (research)

[12] The study program, available at: https://npp.wisc.edu (June 7, 2018).
[13] SCAN Certificate, available at: https://www.law.upenn.edu/live/news/5382-scan-certificate-helps-law-students-use (June 7, 2018).

– whether he will be a neuroscientist with basic legal knowledge or a lawyer with basic neuroscientific knowledge (Shen, 2017).

We who have chosen neuroscience as the secondary field of our research are obliged to have imagination. We must be passionate and have high expectations. At the same time however, we also must be patient, persistent and rational. We must not be complacent and inactive, merely waiting for *that* great neuroscientific discovery. To the contrary, we need to be proactive, always taking the initiative and asking ourselves: »What else can we do for neurolaw?«. After all, neuroscience is not an elixir, some magical potion which will solve all (neuro)legal problems by itself. It can only offer discoveries that are of great help to legal science. But at the end, the creation of that »neurolegal magic« will rest with us lawyers (Shen, 2017).

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