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Advancement of neuroscience and the assessment of mental state at the time of offense

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ABSTRACT

Neuroscience has the benefit of illuminating the neural correlates of behaviors that are of interest to the legal system. This raises the optimism that neuroscience will be able to considerably and appropriately address some perennial problems besetting the legal system. Notable among them are the determination of: (1) criminal responsibility; (2) mental states at the time of offense; (3) competence to stand trial (also known as fitness to plead or adjudicative competence); and (4) whether a defendant is telling the truth. Whereas previous discussions have focused mainly on criminal responsibility, the present review is limited to the assessment of mental states at the time of offense as a legal pre-requisite for determining criminal responsibility in trials involving defendants claiming mental incapacitation (insanity defense). This is one of the challenging forensic assessment endeavors, attracting public criticisms following acquittals based on the insanity defense. We canvas the relevant neuroscientific evidence to elucidate how neuroscientific advances can be applied to help improve upon the assessment of mental states at the time of offense examinations. We examine neuroscience assessments of intention, knowledge of the nature and quality of an act, knowledge of wrongness of an act, as well as decision-making. We conclude that neuroscience assessments would be useful as a complementary data source in insanity evaluations. Clinical opinion based on neuroscientific findings as well as psychosocial data (biopsychosocial assessment) would help to improve upon assessment results.

1. Introduction

The application of neuroscientific advances and evidence in the legal arena has influenced the creation of neurolaw: a discipline interested in exploring the effects of neuroscientific discoveries on legal rules, standards, and proceedings (Jones et al., 2013). Although neurolaw is a relatively young field, it is expanding at a high pace (Jones et al., 2013). The present study examines the application of neuroscience to assess mental state at the time of offense.

Technically, law and neuroscience have different professional focus and interest. However, law has engaged neuroscientific evidence in the quest to deliver justice (Moriarty, 2008). In general, the legal system has found some utility in neuroscientific evidence, owing to its ability to illuminate the biological bases of behaviors of interest (Moriarty, 2008). Lawyers are alert for scientific developments that can help them defend their clients successfully, and so may find neuroscience advances very promising (Jones et al., 2013). Albeit, the relevance of neuroscience to law depends strictly and expressly on the psycho-legal issue at hand, neuroscientific evidence can help the law in at least seven ways (Jones et al., 2013). These are: (1) buttress the evidence provided by non-neuroscientific methods such as psychiatry report, thereby, increasing the confidence of jurors or judges on a conclusion; (2) challenge other evidence types presented at trials; (3) detect the existence of legally relevant facts, such as brain injuries, pain or whether someone is lying; (4) separate (sort) people into meaningful groups for specific purpose (e.g., people likely to respond to rehabilitation); (5) provide new methods for legal purposes such as reducing recidivism; (6) explain decision pathways; and (7) predict future behavior (e.g., future violent behavior) (See Jones et al., 2013, for details).

Indeed, empirical evidence on the admissibility of neuroimage evidence in the courtroom suggests that the law has benefited from neuroscientific evidence. For instance, in Roper v. Simmons (2005), neuroscience evidence establishing the relationship between brain immaturity and behavior appeared to have contributed to the decision of

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the Supreme Court of the United States to rule out the death penalty for a defendant who was less than 18 years old. Similarly, in Commonwealth of Pennsylvania v. Pirela (2007), death penalty was deemed unjustifiable or inappropriate for the defendant partly because of the neuroimaging evidence of frontal lobe dysfunction as proof of diminished responsibility (see Moriarty, 2008, for a review of neuroimage evidence in the U. S courts). These developments suggest that neuroscience and the law have established some working relationship.

It is the expectation of many legal professionals and researchers that neuroscientific advances will be able to adequately and appropriately address some perennial problems besetting the legal system (Batts, 2009; Bennett, 2009; Eastman & Campbell, 2006; Jones et al., 2013; Meynen, 2013; Wasserman & Johnston, 2014; Witzel et al., 2008). Notable among them are the determination of: (1) criminal responsibility; (2) mental states at the time of the offense; (3) competence to stand trial (also known as fitness to plead or adjudicative competence); and (4) whether or not a defendant is telling the truth. From clinical assessment perspective, the latter can be construed as whether a defendant is malingering on clinical measures. The present review focuses on mental states at the time of offense because it has attracted professional, research and public attention over decades, forming the basis of many legal decisions, including criminal responsibility and dispositions. More specifically, issues concerning mental state at the time of offense are central to the criminal adjudication process in instances where the insanity defense is invoked. A defendant can be found guilty but may not be held criminally liable owing to a defective mental state. Acquittals based on defective mental states have been met with fierce public criticisms and uproar, especially in high profile cases such as John Hinckley's attempted assassination of former U. S president, Ronald Reagan (Costanzo & Krauss, 2012). Given that a retrospective assessment of mental state at the time of offense is quite a challenging endeavor, it will be useful to examine how neuroscience can contribute to undertaking insanity evaluations.

In most jurisdictions, to be held criminally liable, blameworthy or punishable for any criminal act (actus reus), the law requires that the accused is capable of or has the ability to form the necessary intent (mens rea). Mental illness is one of the common conditions that can impair the formation of intent. As a result, many jurisdictions, especially common law jurisdictions, have enacted a special legislation referred to as the insanity defense (Adjorlolo et al., 2019). The defense is intended to acquit offenders whose crimes were linked to mental illness (i.e., not guilty by reason of insanity: NGRI). However, guilty but mentally ill or guilty but insane has been adopted as alternative verdict in some States in the U. S (e.g., Arizona, Alaska, Georgia; see Costanzo & Krauss, 2012), and in other jurisdictions such as Ghana; a former British colony (Mensah-Bonsu, 2009). Some jurisdictions, for instance Sweden, have also abolished the insanity defense (see Lund et al., 2011). This said, the insanity defense remains a topical issue (Adjorlolo et al., 2019).

Contemporary insanity defense legislations date back to the case involving Daniel.

M'Naghten who mistakenly killed the private secretary of the then British Prime Minister, Robert Peel (Wondemaghen, 2014). M'Naghten was found to be mentally incapacitated at the time of committing the crime, hence NGRI. His acquittal eventually led to the codification of insanity defense standards, termed the M'Naghten Rules. The Rules state that for insanity defense plea to be successful, it must be proven that: (a) the party accused was laboring under such a defect of reason, from a disease of the mind, as not to know the nature and quality of the act being committed or (b) if the accused did know it, that he or she did not know that the act was wrong (Adjorlolo et al., 2019; Wondemaghen, 2014).

2. Legal requirements in insanity defense standards

There is a significant number of inmates who are mentally challenged compared to the general population with psychiatric disorders (Gottfried & Christopher, 2017). Could the high number of inmates with psychiatric disorders result from an impaired mental state of these people at the time of committing the offense? Could these people plea the insanity defense? This is because their mental impairment (for instance, those with intellectual disability) may put them at a reduced cognitive functioning, hence they may easily become perpetrators or even victims of crimes (Mosotho et al., 2020). The M'Naghten Rules explicitly emphasize know the nature, quality and the wrongness of an act. Some jurisdictions such as Ghana also emphasize the Know component. Section 27 of Criminal Offences Act, 1960 (Act 29) of Ghana states: “If that person was prevented, by reason of idiocy, imbecility, or a mental derangement or disease affecting the mind, from knowing the nature or consequences of the act in respect of which that person is accused” (Mensah-Bonsu, 2009, p. 50). However, other jurisdictions have extra requirements. The Model Penal Code developed by the American Institute of Law requires that a defendant's inability to conform his conduct to the requirements of the law should arise from a mental disorder (Meynen, 2013). According to the Durham Rule in U. S, criminal act is a product of mental defect or disease (Zapf et al., 2014). The Canadian Criminal Code also requires that a mental disorder should make “the person incapable of appreciating the nature and quality of the act or omission or of knowing that it was wrong” (Zhao & Ferguson, 2013, p. 640). Similarly, according to the Chinese Criminal Code, mental illness should make a person “unable to recognize or unable to control his own conduct” (Zhao & Ferguson, 2013, p. 639). (Interested readers are referred to Bal & Koenraadt, 2000, for discussions on insanity defense legislations in Norway, Denmark, Germany, Netherlands, and Belgium).

Although there are jurisdictional differences, generally, the law on insanity defense is not interested in the presence of mental illness per say. Rather, the relationship between the mental disorder and the crime in question. As stated previously, it is the question of whether intent to commit the crime is absent or severely compromised by mental disorder (Bal & Koenraadt, 2000).

3. Forensic evaluations of mental state at the time of offense

Criminal responsibility must be critically weighed, taking into consideration a number of factors including the mental state of the accused (Grossi & Green, 2017). When mental illness is claimed for an offense, the court relies on evaluation reports produced by forensic psychiatrists and/forensic psychologists in the adjudication process. Stated alternatively, forensic evaluations are very instrumental in assisting the court to determine whether a defendant actually labors under the defect of mental illness at the time of committing the crime. This is very essential because the pronouncement of guilt or absence of it has serious consequences such as compromising the safety of society or depriving the accused of their innate right and freedom due to incarceration. Also, the need to know the extent of severity and persistence of mental illness of an accused should be considered (Grossi & Green, 2017). Insanity evaluations have largely relied on psychosocial data collected via: (1) interviews with defendants, and sometimes with significant others; (2) administration of traditional and/or forensic assessment instruments; and (3) third-party information, including collateral reports, witness statements, victim statements if applicable, police reports, previous medical and psychiatric histories (Adjorlolo et al., 2019; Zapf et al., 2014). Based on the information gathered, forensic psychiatrists or psychologists attempt to disentangle mental state at the time of offense from present mental state. The difference provides useful information to estimate mental state at the time of offense. However, this is often difficult since in most cases, the offenders have to be “stabilized” with psychotropic medications before assessments are undertaken. The ability of offenders to recall events or behaviors leading up to or occurring at the time of the offense is particularly challenging. The administration of standardized tests also presents additional challenge. This is the case when the offenders do not cooperate meaningfully. Third-party information or collateral information, and crime scene data sometimes do not also concur. In general, conflicting accounts are inevitable in mental state examinations. Amidst all the challenges, the examiner is expected to reconcile accurately the evidence gathered to form opinion about the presence of mental disorder (including characteristics such as type, severity, possible duration etc.) at the time of the offense. The most important requirement is the opinion about the effect of mental disorder on the commission of the crime, i.e., causal relationship between the mental disorder and the crime (see Zapf et al., 2014, for a comprehensive review of assessment of mental state at the time of offense). The evaluation report is scrutinized by the referring court, and is also subjected to cross examination, mostly in adversarial judicial system. Despite the conspicuous challenges, forensic psychiatrists and/forensic psychologists have contributed immensely to the adjudication process of offenders claiming insanity in jurisdictions that allow the insanity defense.

Researchers have expressed concerns about the validity and quality of forensic assessments, including insanity evaluations (Fuger et al., 2014; Gowensmith et al., 2013; Nguyen et al., 2011). To improve upon forensic examinations in general, there have been discussions on incorporating neuroscientific research techniques and principles (Bennett, 2009; Meynen, 2013; Wasserman & Johnston, 2014; Witzel et al., 2008). A well-discussed area in applying neuroscientific technologies is criminal responsibility assessment (Aharoni et al., 2008; Batts, 2009; Eastman & Campbell, 2006; Meynen, 2013; Wasserman & Johnston, 2014; Witzel et al., 2008). This is connected to the idea that neuroscience has become sophisticated to delineate the neural correlates of different behaviors, including criminal behaviors. However, the usefulness of neuroscience in forensic examinations has been approached cautiously. Thus, there is a wealth of scholarship debating and discussing issues relating to the opportunities, threats and limitations of applying neuroscience in law. This notwithstanding, the proliferation of neuroimage evidence in courts, and the admittance of the neuroimage evidence in some cases (Moriarty, 2008) have reinforced optimism in the potential of neuroscience to contribute significantly to criminal responsibility evaluations. These neuroimages include pieces of evidence as adduced by Functional Magnetic Resonance Imaging (fMRI) and Magnetic Resonance Imaging (MRI) investigations. These imaging techniques respectively, suggest the possible functional and structural changes that the brain of the accused may be undergoing during the time of the investigations. Additionally, a relatively newer technique, the Diffusor Tensor Imaging (DTI) can be used to detect defects in the white matter of the brain. This approach enables us to evaluate the brain's neural or structural connectivity as parametres such as fibre or axonal orientation and strength can be determined.

Whereas previous discussions have focused colossally on criminal responsibility as a broad concept, the present study focuses narrowly on the application of neuroscientific advances in determining the mental state at the time of offense. It also aims to assess the potential of these advances to improve upon insanity evaluations. Indeed, neuroscience is increasingly uncovering the neural correlates of psychological concepts such as freewill, consciousness, moral judgment, decision-making, and the self (Witzel et al., 2008), which may be useful for forensic assessment endeavors. Given these developments, the study will examine the neural correlates of intention since it is the foundation of the insanity defense (Wondemaghen, 2014). In addition, the neural correlates of "know the nature and quality of the act" and "know the act was wrong" (M'Naghten Rules) will be investigated. Furthermore, the extent to which defective decision making might translate into requirements in insanity defense standards, such as appreciate, control, and recognize will also be examined.

The more we know about the cognitive and neural correlates of certain constructs in insanity defense standards, the more we would be able to adequately assess the potential utility of neuroscience in insanity evaluations. This endeavor will also inform and direct researchers interested in exploring the brain basis of insanity defense standards. This may also facilitate the acquisition of the needed resources and logistics to expand and advance neuroscientific applications in forensic practice. By doing so, opinions in insanity evaluations would be based on biological and psychosocial data (biopsychosocial approach), which may help to improve upon the evaluations.

The overarching goal of the present study is to examine how neuroscientific advances can be applied to assess mental state at the time of offense. Firstly, we review evidence for brain pathologies in mental disorders commonly diagnosed in defendants claiming insanity at the time of offense such as psychosis/schizophrenia (Adjorlolo et al., 2019). Evidence for brain abnormalities would, also, determine the potential contribution of neuroscience in insanity evaluations. Secondly, we discuss the application of neuroscience in insanity evaluations. Lastly, the findings are discussed briefly, together with recommendations.

4. Mental illness at the time of offense and functional and structural brain deficits

The presence of mental disorder at the time of offense is crucial to the successful use of insanity defense. Over a decade (2004–2019) review of the insanity defense literature revealed a range of mental disorders (Adjorlolo et al., 2019). The most occurring include schizophrenia, psychosis, major depression, bipolar disorder, substance abuse disorder, personality disorders (e.g., antisocial personality disorders, borderline personality disorders), and mental retardation.

Schizophrenia is a debilitating disorder characterized by positive and negative symptoms.

The positive symptoms include auditory hallucinations, paranoid delusions, or disorganized speech and thinking, while the negative symptoms include flattened affect, loss of a sense of pleasure, loss of will or drive, and social withdrawal (Schultz et al., 2007).

Neuroimaging studies have found prefrontal deficits in schizophrenic patients (Larquet et al., 2010; Shin et al., 2015), although other brain regions such as the parietal cortex (Teixeira et al., 2014), and limbic cortex (Hanlon & Sutherland, 2000) have also been implicated. A fMRI study designed to assess social perception in schizophrenic patients found lower activity in the dorsolateral prefrontal cortex (Shin et al., 2015). Additionally, DTI has shown a significant reduction in fractional anisotropy in brain regions such as arcuate fasciculus, corpus callosum, cingulum bundle and fornix of schizophrenic patients (Kelly et al., 2018; Whitford et al., 2011, pp. 1–7). This is indicative of axonal abnormality (for instance, damage to white matter tract coherence, destruction of the axonal membrane and reduction in myelination of axons as well as axonal packing density) (Kubicki et al., 2005; Whitford et al., 2011, pp. 1–7).

Major depressive disorder is characterized by depressive mood, decreased energy and interest in performing general activities, psychomotor retardation, appetite disorders, and suicidal thoughts (American Psychiatric Association; APA, 2013). Neuroimaging studies have revealed the involvement of the nucleus accumbens (Teixeira et al., 2014), prefrontal cortex and amygdala (Rive et al., 2013), and dorsal anterior cingulate cortex and insula (Hamilton et al., 2012) in major depression.

Bipolar disorder has two phases: depressive and manic, each with distinct clinical features. The features in the manic phase include inappropriate speech and behavior, distractibility, a tendency to make decisions associated with potential painful consequences, and increased goal-directed behavior (APA, 2013). The features of the depressive phase include, difficulty making decisions, motor slowing, a lack of concentration, and changes in memory (APA, 2013). Structural and functional brain imaging studies in bipolar disorders found the involvement of the prefrontal cortex (e.g., lateral orbitofrontal cortex, medial orbitofrontal cortex), the parietal cortex (Teixeira et al., 2014), and the amygdala, thalamus, and basal ganglia (Clark & Sahakian, 2008). Also, patients with substance abuse disorder have also shown impaired prefrontal cortex in neuroimaging studies (Goldstein & Volkow, 2011), likewise patients with antisocial personality disorder (APD). A review of functional neuroimaging found evidence for hypo-perfusion in the frontal lobes in APD (Wahlund & Kristiansson, 2009). In addition, a meta-analysis of 31 functional imaging studies revealed stronger association between antisocial behaviors and dysfunctional prefrontal cortex, specifically the orbitofrontal cortex, dorsolateral prefrontal cortex, and the anterior cingulate cortex (Yang & Raine, 2009). Individuals with psychopathic traits have also been found to be deficient in empathetic abilities; the set of abilities needed for prosocial behavior and moral development (van Dongen, 2020). Among persons with limited or no empathy, evidence suggests structural and functional alteration in critical brain regions, including the anterior insula (AIC), anterior mid and dorsal anterior cingulate cortex (ACC), and periaqueductal gray (Lamm et al., 2011).

Although the evidence reviewed is based on mentally ill patients, it, nonetheless, provides a gauge of brain pathologies in offenders whose crimes are linked to mental disorder (insanity acquittees). It is evinced from the review that neuropathology in the prefrontal cortex underlie majority of the disorders diagnosed in insanity acquittees. The ongoing elucidation of the brain correlates in mental disorders has raised the optimism of the usefulness of neuroscientific evidence in insanity determination.

5. Neuroscience mechanisms in determining mental state at the time of offense

This section examines the mechanisms through which neuroscience can contribute to assessing mental state at the time of offense. The potential utility of neuroscientific advances may be tied to its ability to, among other things, locate the neural networks responsible for the various mechanisms (e.g., intention) as well as demonstrate where these neural networks are located. The present study focused on the application of neuroscience in these two critical areas.

5.1. Neuroscientific assessment of intention

One major requirement in forensic evaluations is to ascertain whether the presence of mental disorder at the time of offense "significantly" impaired intention formation. The available evidence suggests that the neural basis of intention is located in the presupplementary motor area (pre-SMA) (Boccardi et al., 2002; Haynes et al., 2007; Lau et al., 2004; Sumner et al., 2007). In an experimental study (Lau et al., 2004), found that the pre-SMA was activated when participants responded to their intentions to undertake a task. Studies have, also, found that patients with lesions in the pre-SMA reported no activations on cognitive tasks, compared to healthy controls (Boccardi et al., 2002; Haynes et al., 2007; Lau et al., 2004; Sumner et al., 2007). These findings suggest that dysfunctions arising from the pre-SMA may negatively affect an individual's ability to form the necessary intentions to carry out a crime. Most pertinently, some researchers (e.g., Haynes et al., 2007; Lau et al., 2004) have been able to disentangle intention from the ability to carry out an act. This raises the possibility that mentally disordered offenders (MDOs) can commit crimes without the requisite intentions associated with the crimes. By extension, a crime can occur when the "storehouse" of intention (pre-SMA) is impaired. Individuals with damage to pre-SMA can still have the intact ability to carry out crimes by responding to environmental and other non-intentional sources of information (Aharoni et al., 2008). For MDOs, these sources could be the content of commanding voices (auditory hallucinations), visual stimuli (visual hallucination), or false beliefs (delusions). On these bases, neuroscientific evidence on the activities of the pre- SMA could help determine whether offenders were capable of formulating the necessary intent in relation to the crimes committed.

The pre-SMA is also thought to be responsible for self-control (Boccardi et al., 2002). For instance, Boccardi et al. (2002) found that lesions in the pre-SMA resulted in difficulty resisting picking up an item, suggesting lack of self-control. This might also suggest inability to resist impulses, and therefore can help determine whether MDOs suffer from irresistible impulse. The pre-SMA has, also, been implicated in impulsive behaviors commonly observed in violent offenders, as well as difficulties in avoiding socially unacceptable behaviors (see Bennett, 2009, for review). This can help in irresistible impulse evaluations in jurisdictions with such a requirement (e.g., China, see Zhao & Ferguson, 2013). From the foregoing, it can be deduced that MDOs may have impaired intention formation arising from dysfunctions in the pre-SMA. Therefore, by measuring the activities in the pre-SMA, neuroscientists would be able to determine the capacity of intention formation at the time of carrying out criminal activities.

While the purported localization of intention in the brain may have useful applications in forensic assessments, there are some challenges, presently. First, it is not known how much of activation is required in the pre-SMA that indicates the ability or inability to form intention. Reduced activations might imply that an individual needs less activation to function, and not necessarily impaired intention formation (Aharoni et al., 2008). Secondly, abnormal activations in the pre-SMA can occur as a result of hypoactivation, hyperactivation, positive or negative activation, or erratic pattern of brain activities, which necessarily do not suggest dysfunctional pre-SMA (Aharoni et al., 2008). Thus, it might be difficult to establish when the activations are due to normal or disordered brain processes at the time of offense. Furthermore, disruptions in other brain processes such as a decrease in gray matter may, also, produce deficits similar to those observed in dysfunctional pre-SMA, especially if the lesion is small (Bennett, 2009). The challenge, here, is to determine whether the deficits emanated from impaired pre-SMA and/or other brain regions, and which brain region to assess. Also, because of distributed neural processing and brain redundancy, other neural networks may provide supplementary role or take up intention computations when the pre-SMA is dysfunctional (Aharoni et al., 2008). Thus, dysfunctions in the pre-SMA might not necessarily translate into the overall lack of ability to form intention.

5.2. Neuroscientific assessment of knowledge of nature and quality of act

"Know the nature and quality of the act" is legally construed; however, it is clinically ambiguous and challenging to determine. Forensic Mental Health Professionals (FMHP) conducting insanity evaluations in jurisdictions using this requirement have approached it differently, based on their individual understanding (Witzel et al., 2008). But can neuroscience measure something as ambiguous as "know the nature and quality of the act"? There is evidence that the human brain gains knowledge about actions from two sources: efferent information and afferent information (Aharoni et al., 2008). While efferent information entails information from the brain and spinal cord (central nervous system) to muscles and glands of the body, afferent deals with information from the peripheral system and sent towards the central nervous system (Kandel et al., 2013). In other words, efferent information is governed by motor planning whereas afferent information provides somatosensory feedback (Aharoni et al., 2008). Important to the discussion is motor planning and initiations of behaviors or actions. To gain knowledge of a particular act requires awareness of intentions to perform the act, followed by the perceptual awareness of committing the act (Aharoni et al., 2008). For the individual to possess knowledge of an act, and subsequently inhibit or refrain from committing the act, then the subjective or perceptual awareness of the act must precede the execution of the act (Brass & Haggard, 2007). Otherwise, the act may occur but the person committing it may lack knowledge about its nature and quality. An individual who is deficient in empathetic abilities will have challenges inferring the mental states of others (i.e., deficit in Theory of Mind). This makes it likely that persons with psychopathic traits, for instance, who have been shown to lack empathy will have difficulty knowing the nature, extent of and quality of criminal acts they undertake.

The perceptual awareness of an act is also modulated by the angular gyrus, an area within the parietal cortex (Sirigu et al., 2004). In an experimental study, Sirigu et al. (2004) found that patients with parietal lesions reported when they started moving, only after becoming aware of the intention to move. This finding suggests that impairment in awareness of intention can lead to impairment in perceptual awareness of the act. This will in turn deprive the individual of the knowledge of the nature and the quality of the act. This could apply to MDOs with dysfunctional angular gyrus. Aharoni et al. (2008) argued that offenders, in this case MDOs, with dysfunctional angular gyrus can perform quick behaviors such as pull a trigger before becoming aware of the act. This, also, indicates the possibility that MDOs might know they have committed a crime after the crime had actually occurred. This perhaps might satisfy the requirement of "know the nature and quality of the act".

The decision to inhibit an ongoing act after gaining knowledge of it deserves attention. The human brain network contains a control structure (e.g., the dorsolateral fronto-median cortex) for self-initiation, inhibition or withholding of actions one intended to perform (Brass & Haggard, 2007; Krieghoff et al., 2011). That is, humans have the innate power and ability to control their behaviors via initiations and inhibitions. However, the brain control mechanism for self-inhibition can be incapacitated by dysfunctional structural and functional brain processes commonly seen in patients with mental disorders (Bahraini et al., 2014). This circumstance increases the probability that an individual with mental disorder with corresponding dorsolateral fronto-median cortex damage will have substantial challenges inhibiting ongoing act, even if they have knowledge about its execution. This, also, has implications for the insanity defense incorporating irresistible impulse or those requiring the inability to conform one's behavior to the requirement of the law (Model Penal Code, see above). However, it is not clear the extent of awareness that will enable MDOs know the nature and quality of the crimes committed. Furthermore, as noted by Aharoni et al. (2008), it is not clear whether awareness is a unitary construct or it has other dimensions distributed across the brain.

5.3. Neuroscientific assessment of knowledge of wrongness of an act

Neuroscience can help understand or determine whether people have knowledge of wrongness of their acts based on research into the neural correlates of salient concepts such as moral judgment, social contract reasoning and Theory of Mind (ToM) (Aharoni et al., 2008). As humans interact with others, and engage in various actions, they are, also, required to evaluate the morality of their actions. Studies have revealed that the ability to judge the morality of one's actions is influenced by the integration of cognitive, emotional and motivational mechanisms (Decety & Howard, 2013). Moral judgment has been found to emerge very early in life (around 3 months of age), and continues throughout adulthood (Decety & Cacioppo, 2012, p. 108). Studies that have employed fMRI on both healthy participants and neurological patients have revealed the brain mechanisms implicated in moral thinking or judgment. This network of regions includes the ventromedial prefrontal cortex, dorsolateral prefrontal cortex, medial prefrontal cortex, temporoparietal junction, amygdala, and insula (Avram et al., 2013; Decety & Cacioppo, 2012, p. 108; Hayashi et al., 2014; Koenigs et al., 2007; Young & Dungan, 2011). Damages to these brain regions are very common in patients with mental disorder (see the section on mental illness and brain deficits).

There is evidence that patients with lesions to these brain regions have profound difficulties in judging whether an act or a behavior produced by themselves or by others is wrong (Hayashi et al., 2014; Koenigs et al., 2007; Moll et al., 2005). Thus, dysfunctions arising from these brain regions might suggest that MDOs would be deprived of the knowledge of the wrongness of the act. It is, however, unclear whether impairment in moral judgment is general or specific. That is, whether offenders with lesions to these brain regions will have deficient moral judgment in specific situations or in all situations. One study found that patients with damage to the ventromedial prefrontal cortex do not necessarily lack the capacity to judge the moral wrongness of an act, as their moral judgments were normal in some cases (Koenigs et al., 2007). If so, the challenge is how to demonstrate that during the commission of a particular crime, the offender could not know the moral wrongness of that act. This raises the question about whether there are specific acts in which moral judgment would be impaired after damage to the prefrontal cortex.

Neuroscience investigations of the neuronal basis of applications of social rules (i.e., social contract reasoning) can help to demonstrate whether an act is wrong. Generally, as humans, we coordinate our activities with those around us, care deeply about ourselves and others, and want to be treated in fairly and trustworthy manner: all these processes contribute to a coherent social world guided by social rules (Lieberman, 2007). A social network of inter-dependency is based on clear and explicit social rules. In other words, humans have social contractual agreements to ensure peaceful co-existence. We are bound by this contract to recognize and appraise our behaviors and actions, and their repercussions on others. The rule of thumb is to refrain from engaging in behaviors that are socially undesirable. Interestingly, the ability to engage in or apply social rules in appraising the appropriateness of one's act has neural underpinnings. The brain regions implicated in social rules include the ventrolateral prefrontal cortex, the medial frontal gyrus, left angular gyrus, and the orbitofrontal cortex (Fiddick et al., 2005; Krawczyk, 2012; Krawczyk et al., 2011). The prevailing hypothesis is that dysfunctions associated with social contract reasoning might hinder an individual's capacity to judge any particular social contract violations as right or wrong (Aharoni et al., 2008). In essence, MDOs with concomitant damage to these brain regions may not be able to appreciate the wrongness of their crimes.

Furthermore, neuroscientific research advances in ToM can help assess knowledge about wrongness of an act. ToM refers to reasoning about the mental states of others (Yang et al., 2015). That is, ToM is the ability to predict the relationships between internal states of one's mind and external states of affairs (Frith, 1989). It involves differentiating the reality that others perceive from one's subjective reality (Baillargeon et al., 2010). ToM has been reported to emerge by age four, and continues into adulthood (For review, see Lieberman, 2007). It is a common, effortless, and indispensable part of human reasoning (Fodor, 1987) which help individuals in their daily navigations in the complex social environment (Wan, 2012).

Neuroimaging studies have shown activations in several cortical and subcortical structures, including: medial prefrontal cortex, the temporoparietal junction, the posterior cingulate cortex/precuneus, posterior superior temporal sulcus, and the ventrolateral prefrontal cortex (Bahnemann et al., 2010; Frith & Frith, 2003; Lieberman, 2007; Mar 2011; Saxe & Wexler, 2005). In general, the temporo-parietal junction is associated with evaluating others' mental states, particularly from third-person perspective (Carter et al., 2012). In one study, when the participants were tasked to attribute beliefs and desires to another person, it was found that the temporo-parietal junction was activated (Saxe & Wexler, 2005). Abnormal activations (i.e., hypoactivations) in the temporo-parietal junction result in two conditions. The first relates to deficit in ToM (e.g., inadequate belief attribution), and the second involves over-attributions of others mental state (Aharoni et al., 2008). MDOs with deficit in ToM may be unable to judge the wrongness of their acts. Similarly, frightening delusions can be the result of the over-attributions of others' mental states (Aharoni et al., 2008). MDOs can over-attribute others' mental states to mean that people are planning evil against them (persecutor delusion), gestures or comments of people are directed at them (delusions of reference), or that someone in love with them (erotomanic delusion). In sum, the inability to appropriately and accurately recognize the mental states of others, either arising from deficits in ToM or over-attributions, could provide biological basis to determine whether MDOs have knowledge of the wrongness of their crimes.

Despite the above promising potential of neuroscience in contributing to detecting whether or not MDOs have knowledge of the wrongness of their actions, the major challenge is that, there could be other brain regions holding cues to determining the knowledge of wrongness of act that have not yet been detected (Aharoni et al., 2008). It is, therefore, possible that damages to brain regions, other than those above, may result in deficits in whether MDOs have knowledge of the wrongness of their crimes. In addition, depending on the extent of deficits in ToM, individual can extract moral information by observing the behaviors of others in the environment (Aharoni et al., 2008).

5.4. Neuroscientific assessment of decision making in insanity

Neuroscientists have been interested in elucidating decision-making deficits in patients with mental disorder (Hori et al., 2014; Larquet et al., 2010; Struglia et al., 2011). Deficits in decision making have been suggested as one of the mechanisms influencing the commission of crimes by MDOs (Meynen, 2013). Kalis et al. (2008) categorized decision-making process into three stages. The first stage involves generating possible actions to accomplish an act. The second involves selecting the most appropriate actions from the action list generated in the first stage to execute an act. The last stage, initiation of the decision-making process, is where the actions chosen in the second stage are implemented. According to Meynen (2013), the ability to execute each stage of the decision-making process is severely compromised in patients with mental disorders. Thus, decision-making is relevant to the various insanity defense standards, although it is not explicitly stated (Meynen, 2013). Accordingly, deficient decision-making might result in inability to follow appropriate social behaviors. This could lead to difficulties in conforming one's conduct to the requirement of the law (Model Panel Code insanity criteria). Impaired decision-making might also result in challenges in possessing knowledge of the nature and quality of act, or knowledge of wrongness of act (M'Naghten Rules). Compromised decision making processes may also culminate in substantial challenge to appreciate (Canadian Criminal Code insanity criteria) or recognize (Chinese Criminal Code insanity criteria) the nature or quality of the crimes committed. Other ramifications include challenges to inhibit ongoing proscribed act (irresistible impulse). In essence, defective decision-making might satisfy some criteria in the various insanity defense standards.

Neuroscience has evinced that decision making is a biopsychosocial phenomenon (Witzel et al., 2008). Indeed, neuroscientific studies have implicated predominantly the prefrontal cortex (dorsolateral, orbitofrontal, and ventromedial) (Onge et al., 2012; Wilbertz et al., 2012) in decision-making. The prefrontal cortex modulates cognitive functions collectively termed executive functioning. Executive functioning is an umbrella term referring to higher-order, goal-directed cognitive processes, including those related to planning, goal-setting, self-awareness, self-initiation, self-inhibition, self-monitoring, strategic behavior, problem solving, and cognitive flexibility (Hargrave et al., 2012). These abilities are relevant in decision-making in ambiguous and risky situations (Del Missier et al., 2010). Studies comparing clinical patients and normal healthy controls have found gross impairments on decision making tasks (Larquet et al., 2010; Struglia et al., 2011). Larquet et al. (2010) assessed the feeling of regret following the execution of regretful decisions. It emerged that schizophrenic patients, compared to healthy controls, did not report any regret and did not anticipate any negative consequences of their choices. Similarly, using Iowa Gambling Task (IGT) (a laboratory task designed to measure emotion-based decision-making), Struglia et al. (2011) found that schizophrenic patients performed poorly on the task than the normal controls. Patients with attention deficit hyperactivity disorder (ADHD) also reported deficits in decision-making on a combined fMRI and electrodermal neuroimaging tasks (Wilbertz et al., 2012). Another study found that major depressive patients have difficulties making decisions in a social context interaction (Wang et al., 2014). In addition, Witzel et al. (2008) asserted that individuals' emotions have significant influence on decision making even when they have intact decision-making abilities. Accordingly, disordered emotions may affect negatively the decision-making stages described above. Similarly, defective emotions would compromise the ability to undertake voluntary acts. The neural correlates of emotions in decision making, including emotional judgments, are the prefrontal cortex (Coricelli et al., 2007), and the amygdala (Seymour & Dolan, 2008). In summary, by assessing the neural correlates of decision making, including emotion, neuroscience will be able to contribute to the assessment of mental states at the time of the offense.

6. Discussion

As stated previously, the application of neuroscience in insanity examinations may be tied to its ability to among other things; (1) identify the neural networks responsible for the various mechanisms (e.g., intention) and (2) demonstrate where these neural networks are located. This review has found evidence for some of these mechanisms, particularly those relating to neural correlates and their locations.

In general, progress has been made in delineating some brain regions and/or neuronal connections that appear germane for insanity evaluations. Neuroscience can advance the argument that abnormalities in certain brain regions are likely to result in significant cognitive and behavioral dysregulations that are observed in insanity acquittees. The available evidence suggests that the prefrontal cortex and its connections might help neuroscientific investigations to satisfy some of the criteria in insanity defense legislations. Thus, assessments of pertinent neural correlates might help to reveal whether a defendant can formulate the necessary intentions, know the nature and the quality of the act, as well as know the wrongness of the acts. In addition, terms such as appreciate, recognize and conform can be understood with neuroscientific advances. Also, neuroscientific evidence may help determine the decision-making capacity and the emotional states of MDOs at the time of offense.

It should also be noted that lesions to a range of brain regions may be relevant in undertaking neuroscientific assessment of insanity. For instance, damage to the temporal lobes and the limbic system can result in unprovoked anger, memory and intellectual difficulties, behavioral dyscontrol, and difficulty in regulating oneself amidst threatening stimuli (Fabian, 2010). Similarly, because of the rich neuronal interconnectivities, damage to a neural network may affect the functioning of others (Jurado & Rosselli, 2007). Thus, impairment in the prefrontal cortex may result from injuries sustained by the cortex, as well as injuries sustained by other connected cortical and subcortical structures. Likewise, damage to the prefrontal cortex may result in damages to the subcortical structures regulating emotion (e.g., the amygdala and hippocampus) (Seo et al., 2008).

Most importantly, neuroscience currently may not be able to independently determine insanity (Gazzaniga, 2006; Morse, 2004). Insanity, and for that matter criminal responsibility, is a human construct that may not be explained by neuroscience whose tenets are only based on cells of the brain (Gazzaniga, 2006). However, neuroscientific assessments may add more objective information to bolster the accuracy and validity of clinical opinions that are based largely on psychosocial data. This was demonstrated by Rigoni et al. (2010) when they assessed the mental state of a woman who committed murder but was suspected to be mentally ill at the time of the crime. The authors incorporated neuropsychological, brain morphometry (neuroimaging using MRI scan), genetic analysis and psychiatric (both clinical interview and Minnesota Multiphasic Personality Inventory, MMPI-2) and the Psychopathic Personality Inventory-Revised (PPI-R) assessment modalities. The neuroimaging data revealed the offender had reduced gray matter volume in the left prefrontal cortex (left middle frontal gyrus, left superior frontal gyrus), lateral temporal cortex and the superior occipital cortex, compared to the control group. The psychiatric and neuropsychological data, also, revealed that the defendant had a reduced capacity to control her behavior, as evidenced by high impulsivity, poor behavioral control, emotional disorder and borderline personality disorder. As noted previously, impairment in the prefrontal cortex is associated with reduced self-control (also see Bennett, 2009). Thus, neuroimaging evidence of impaired frontal lobe has corroborated the psychosocial evidence on reduced self-control. The assessment has provided holistic data covering the biological and psychosocial indicators of disordered behaviors.

Interdisciplinary approach in forensic assessments will invariably improve the outcome of the assessment. The uncertainties that characterize decision-making regarding mental state at the time of the crime may be reduced substantially with evidence from neuroscience. As noted previously, neuroscience provides a general knowledge which aims at elucidating how brain injuries and mental disorders may prevent an individual from effectively making rightful decisions and taking steps to correct or avoid wrongful decisions. Consequently, clinical opinion based on neuroscientific and psychosocial data will be able to respond appropriately and adequately to the demands of the assessment requests by the judicial system. These assessment results might be able to withstand cross-examinations that epitomize adversarial systems. There is also the tendency for judicial acceptance and confidence in evaluations that are supplanted with neuroscientific data (Greene & Cahill, 2012; Rendell et al., 2010).

There are, however, other substantial challenges for neuroscience to overcome, in addition to the challenges discussed earlier. It is important that neuroscience demonstrates the extent of brain injuries necessary to produce corresponding behavior deficits. This is because, not all lesions and pathologies in the brain regions implicated in insanity evaluations indicate a compromised mental state (Batts, 2009). In addition, not all people with similar brain lesions do commit crimes. Therefore, the mere presence of a brain lesion might not provide enough biological justifications as to why a crime occurred (Gazzaniga & Steven, 2005; Sinnott-Armstrong et al., 2008). Furthermore, the exact mechanisms through which neuroscience can retroactively or retrospectively determine mental states at the time of a crime have not been explicated. The major concern is how evidence of brain lesion at a later date will reveal the true state of the brain at the time of the offense. Even if neuroscientific findings truly reflect the state of brain at the time of offense, the accuracy of neuroscience techniques to detect impairment is also another limitation (Aharoni et al., 2008). Interpreting and relating the neuroimage data to mental state at the time of offense is another major challenge besetting neuroscientific evidence in the courtroom (see Moriarty, 2008, for details). In this regard, it is postulated that neuroscientific evidence may not necessarily meet the legal standard on admissibility or otherwise of scientific evidence. The criteria outlined in *Daubert* and *Frye* by the Supreme Court in the United States include (i) empirical testability, (ii) support from peer review, (iii) error rate and whether acceptable, (iv) general acceptability in the scientific community. In particular, questions remain regarding the acceptance of neuroimaging evidence by the general neuroscience community, as well as the error rates associated with producing neuroscientific evidence and whether they are acceptable. Currently, there is a paucity of empirical data detailing these essential criteria; a development that may have contributed to the slow use of neuroscientific in criminal adjudication.

The ecological validity of neuroscientific findings is another constraint. That is, the extent to which neuroscience findings relate to normal daily behaviors in the social environment (Kasai et al., 2015). Neuroscience has traditionally measured brain activity in laboratory-based settings. These settings are largely artificial, with few or no competing stimuli. This contrasts the real-world environment where individuals, including offenders, are exposed to several competing and interfering stimuli. How the brain functions in these two settings might differ substantially. As a result, laboratory-based measurements might not provide adequate information regarding an individual's brain function in real-world environments. Indeed, ecological validity of neuroscientific findings has been identified as a recurring problem when applying neuroscience in law (Aharoni et al., 2008). Overcoming this limitation involves measuring the action of the brain in the real-world, as this can help to understand the human brain and its mental functions beyond the laboratory settings (Kasai et al., 2015). Therefore, the exact influence of neuroscience data on judicial pronouncements is an area of growing interest that is yet to be seen.

7. Conclusion

The complex and challenging task involving assessing mental state at the time of offense apparently may not be answered satisfactorily by neuroscience alone. It will prove very useful as a complementary data source in insanity evaluations. Clinical opinion based on neuroscientific findings as well as psychosocial data (biopsychosocial assessment) would help to improve upon assessment results in the legal system.

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