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Brain Imagistic Investigations and Electroencephalography in Forensic Psychiatry

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ABSTRACT: Forensic psychiatry is a complex expertise domain that is required to objectify human antisocial behavior and bring quantitative arguments to the law regarding discernment. The law expects clear and undeniable evidence when investigating a criminal offence. Still, there are many subjective elements in the process of evaluating one's psychological and cognitive state, especially when evaluating discernment at the moment of the crime and not at the moment of evaluation. Psychological test batteries, standard examination protocols and multiple forensic board presentations should eliminate possible errors but more investigation techniques could increase the efficiency of the forensic psychiatric report. As such, this article proposes a literature review over the imagistic and electroencephalographic (EEG) examinations that could open new perspective for standard forensic psychiatric protocols. Absence of discernment, organic pathologies and severe psychiatric disorders were left out of the subject of this article, focusing on personality, behavior and affective disruptions.

KEYWORDS: forensic, psychiatry, electroencephalography, brain, MRI

Introduction

Psychiatry has complex medical and psychological variations and calibration of such variations is difficult, especially within a criminal investigation, where every detail can be subjected to doubt and could change the course of the process. This is one of the reasons why, neurobiology and functional evaluation of brain and behavior is starting to become an important research subject in the medical field.

EEG and brain radiology are the focus of the research and though they still need to be adjusted to forensic protocols, this approach is becoming closer to practical field every day, as forensic radiology has entered autopsy and anthropology laboratories.

Besides it is diagnostic involvement, functional examination could promote rehabilitation strategies for the forensic population. This is why neuroscience should complete the psychiatric field in criminal investigative protocols. Leaving aside brain organic pathologies and chronical diseases that can be easily corroborated with discernment from a clinical point of view, there are more sensitive elements for an apparently normal brain to be examined, such as behavior, impulse control, emotional processing, personality alterations and affective disorders. Although these are all entities processed by the central nervous system and they should be controlled and adjusted for an efficient social integration, any modification in the neuro-bio-chemical balance could lead to disrupted behavior and stimuli response. Although discernment is not affected by these disbalances, an objective analysis and possible corrective

interventions should be available next to a pragmatic forensic expertise (Huebner, Vloet, Marx, Konrad, Fink, Herpertz and Herpertz-Dahlmann 2008, 542).

The Electroencephalogram (EEG)

The applications of EEG in neuropsychiatric field are important in the diagnostic and surveillance of epilepsy, encephalopathy, sleep disorders, coma grade evaluation and other neurologic disorders. It is a non-invasive investigation that detects, increases and records the brain's electrical activity. Also, the EEG is a functional examination as it can record the activity changes during light stimulation, eye opening and other motor and external stimuli. Until recently, the EEG was limited to neurologic diagnostics but given the known areas of the brain that process behavior and emotions, there were questions whereas certain other external stimuli could trigger altered responses in those areas and the examination could record specific affective and behavioral disorders. Of course, every EEG evaluation should be completed by all psychological and psychiatric data and integrated in the expertise (Mednick, Vka, Gabrielli Jr. and Itil 1981, 223).

First of all, psychological testing and psychiatric assessment, should set the premises for the EEG functional evaluation. Most of the studies in this field were conducted on consistent delinquency acting patients with certain behavioral traits such as: lack of responsibility, alcohol abuse, repeated aggressiveness towards others, poor impulse control. Emotional disturbances were studied in cases of psychopathic personality disorder. Also, organic pathology and patients on medication have been eliminated from studies because of the interferences and clear involvement of the somatic disruption with the EEG results and psychiatric symptoms. Control groups were also evaluated in the same form as the study groups and the differences in the results were stated as an additional argument. Most observations concluded that there is a high prevalence of modified results in the EEG examination in the offender group compared with control group (Vendemia, Caine and Evans 2006, 15).

As such, the temporal lobe and the parieto-occipital area showed the most of the alterations, with heightened delta wave activity and lower alpha activity in these specific regions. Beyond its auditory role, the temporal lobe is a center for memory and emotional processes and it integrates certain elements of visual perception. Also, in this area is a center for empathic processing which has been a subject for psychopathic traits studies. In matter of emotions, parieto-occipital area handles sadness, disgust and happiness aside from being a visual area. As these disruptions appear on the EEG, an assumption could be made that external stimuli, processing emotion and behavioral response are the main modified characteristics of the brain neurobiology in forensic population. According to this assumption, there is a possibility that a functional examination context, such as, a specific visual stimulus, could intensify the disruptions in the affected areas of the brain (images of the accused offence, violent or strong emotional stimuli). Another theme for study is the coordination of how these processes take place in both of the cerebral hemisphere and whether there is a symmetric activity (Reyes and Amador 2009, 60).

Another EEG feature could recognize emotional signals from different areas of the brain by applying similar stimuli with different outcome. For example, showing a video with a random violent image and showing a scene from the evidence collected against the offender could trigger different parts of the brain such as temporo-parietal area for empathic traits or cognitive areas such as prefrontal cortex. The presumption is that neutral violence could trigger emotional activity and self-involved scenes could trigger more cognitive activity which could also include simulation traits. EEG has been used in some studies for detection of depressive symptoms and medication response and some cases showed that some patients had changes in the electrical activity of the

affected brain areas but were persistent in showing the same symptoms. As such, mapping emotional EEG activity could offer at least the presumption for dissimulation and simulation during forensic psychiatric expertise, enforcing the characteristics resulted from psychologic testing (Lindberg, Tani, Virkkunen, Porkka-Heiskanen, Appelberg, Naukkarinen and Salmi 2005, 12).

Based on the emotion recognition, the examination could lead to personality information and behavioral pattern recognition. As the affective level is a foundation for personality development, emotional mapping with the EEG could draw a prediction scheme for personality neurobiology. Of course, these findings should be corroborated with psychological test batteries during these studies. There are two theories about brain networking that could set the foundation for this type of evaluation. The first takes into consideration the consistency of brain matrix over time and the second concept takes into consideration the dynamic processes of brain activity, especially in different age ranges. Again, alpha waves in the cingulate cortex and theta waves in the temporal lobe were most coordinated features during these studies in both agreeable and neurotic features.

Even if the EEG is a non-invasive procedure, it still holds multiple variables that could interfere with the objectiveness of the forensic investigation. Given the absence of linearity in the normal EEG diagram and the peaks that could be interpreted differently, the lack of standard stimuli for an emotional analysis and for personality traits, the fact that it gives presumptive results even in clinical pathologies with need of additional investigative techniques for certitude, the EEG remains a more qualitative and not quantitative measure tool during forensic psychiatric protocol. Still, it would make a good future tool for clinical studies and some of the antisocial traits in offenders could be studied in parallel with the standardized evaluation (Niv, Ashrafulla, Joshi, Raine, Leahy, Baker and Tuvblad 2018, 431).

The computed tomography

In the same record of bringing objectiveness to the act of forensic psychiatric evaluation, we move to the possibility of using brain CT evaluation. This feature is most commonly used for the diagnostic of brain organic pathologies but the theory we present is using it for the assessment of personality and behavioral aspects in criminal offenders. Given the specifics of the CT investigations, most studies have chosen single photon emission computed tomography (SPECT) and positron emission tomography (PET) as instrument for analysis of the brain emotional activity with specific contrast substances in order to highlight the brain regions involved in the process. Emotional traits are weighing the most part of the motivation of one's activity. CT has been used for certitude diagnostic in pathologies like stroke or dementia and more recently, even in autistic spectrum disorder. Many lesions have been corroborated with abnormal affective characteristics and behavioral disruptions. The question is, if in the absence of those organic lesions, some changes of personality traits could be evaluated by brain imaging (Kuruoglu, Arikan, Vural, Karataş, Araç and Işik 1996, 350).

The baseline for the hypothesis resides in the literature where most studied personality feature is the borderline personality disorder, a clinical feature with no organic underline and abrupt behavioral and emotional alterations. Bringing a functional feature within the CT scan was used in order to observe the brain`s active metabolism and processing in different areas. As such, PET scans showed an inverted relationship between aggressive behavior and glucose usage in the prefrontal cortex and also, borderline patients showed a completely different activity in the prefrontal area compared to control groups. The prefrontal area is an important cognitive hub for

behavioral control and decision making (Schulz, Camchong, Romine, Schlesinger, Kuskowski, Pardo, Cullen and Lim 2013, 535).

Also, another study describes a decrease in the glucose metabolism of the brain in the temporal and parietal lobe but also in the motor cortex (De la Fuente, Goldman, Stanus, Vizuete, Morlán, Bobes, Mendlewicz, 1997). An interesting observation was that in female patients with personality disorder there was a hypermetabolic rate of glucose usage in the nucleus accumbens which is a hub for expressing motor responses to stimuli, such as impulsivity and aggressive behavior in emotional circumstances. This trait could explain the lack of impulse control and hyperemotional characteristic of female offenses (New, Hazlett, Buchsbaum, Goodman, Mitelman, Newmark, Trisdorfer, Haznedar, Koenigsberg, Flory and Siever 2007,1632).

Another study, demonstrated that, in patients with impulsive aggressive behavior, there was a decreased fluoxetine metabolism in the orbito-frontal area and adding fluoxetine in the treatment protocol resulted in relatively important reduction of aggressivity and normalizing the brain activity in the orbitofrontal cortex (New, Hazlett, Newmark, Zhang, Triebwasser, Meyerson, Lazarus, Trisdorfer, Goldstein, Goodman and Koenigsberg 2009, 1110).

Hostile behavior and aggressiveness were also associated with low glucose usage in the frontal brain regions but also in the posterior areas of the brain but also in the fronto-temporal white matter, insula and striatum which are important hubs for action control and impulse response (Bøen, Hjørnevik, Hummelen, Elvsåshagen, Moberget, Holtedahl, Babovic, Hol, Karterud and Malt 2019, 260).

SPECT scans also concentrated upon brain perfusion that mirrors the activity of those specific areas. Impulsivity and aggressiveness have been correlated to hypoperfusion in the temporal and prefrontal lobe which are decision and emotional processing areas (Goethals, Audenaert, Jacobs, Van den Eynde, Bernagie, Kolindou, Vervaet, Dierckx and Van Heeringen 2005, 190). Also, an experimental induced aggressive stimulation showed that patients with borderline personality presented a hyperactivity of the orbito-frontal cortex, thus, in a decision-making area (New, Hazlett, Newmark, Zhang, Triebwasser, Meyerson, Lazarus, Trisdorfer, Goldstein, Goodman and Koenigsberg 2009, 1112). Also, for impulsive personality traits, PET scan with fluorodeoxyglucose was used as a serotonergic agent which abruptly activated the orbito-frontal area in these patients (Hoptman 2003, 271). Serotonergic activity has been studied by using activation markers and it appears that serotonin has implications in aggressiveness and impulse control as PET scans showed a significantly lower serotonin activity in the nucleus accumbens in patients with impulsive aggressivity (Frankle, Lombardo, New, Goodman, Talbot, Huang, Hwang, Slifstein, Curry, Abi-Dargham and Laruelle 2005, 919).

As it can be seen from different studies, aggressive, impulsivity and emotional disruption in personality disorders can be mapped and demonstrated with CT scan variants as long as functionality of the areas involved can be actively illustrated. This perspective opens new possibilities not only for studying antisocial features but also for clinical and psychological management and prevention.

Magnetic Resonance Imaging

In matter of high-standard neuroimaging, MRI brings the most objective and evident diagnostic proofs. Within forensic psychiatry evaluation, functional MRI (fMRI) has the most potency as it cand examine and demonstrate detailed neurobiological aspects of one's behavior and emotional processing. Aside from being one of the most powerful diagnostic tools for brain lesions and injuries, as it can reveal profound anatomical and functional disturbances, it reveals changes in the brain's chemistry and networking

through different contexts and stimuli. the most important feature of fMRI is the possibility of placing the patient in a certain context and inducing him certain emotional states with visual and auditive triggers.

In matter of antisocial personality traits, the most common structural and functional disturbances point to the prefrontal cortex. High psychopathic levels in psychological testing have been associated with volume and/or thickness reduction of the prefrontal grey matter, compared to control. Interestingly, some studies showed more or less, the same findings in people with aggressive behavior and low education rates or alcohol abuse. Also, violent offenders, murderers and impulsive aggressive patients have been examined with fMRI and results demonstrated a lower functional rate of the orbitofrontal area and lower inhibitory function when they were given angry faces to visualize (Žarković Palijan, Radeljak, Kovač and Kovačević 2010, 255).

Psychopathic patients have been given emotional and cognitive tasks and compared to controls, the left ventrolateral cortex and the anterior cingulate cortex showed disturbances in differentiating concrete and abstract stimuli. also, in the ventrolateral cortex there was an important decrease of activity in violent offenders when they were shown moral violation videos or images. On the other hand, one study showed that non-convicted psychopaths show similar function of the prefrontal cortex compared to healthy individuals whereas convicted patients showed a reduced volume of the gray matter compared to controls. This suggest that, initially, psychopathic offenders need normal frontal cortex functioning for anticipation and premeditating their crimes. All these findings record good coordination between behavior and emotional disruption and the role of the specific examined areas in the processing of those traits. The prefrontal cortex is an important executive hub while the orbitofrontal and ventromedial area are specialized in emotional filtering, reward processing impulse management. Also, medial prefrontal cortex and parieto-temporal area have been linked to empathy and compassion which promote social integration and functionality. Impaired activity in these areas have been demonstrated by functional MRI in both adult individuals with psychopathic traits but also in children with callous unemotional, which is a strong predictor for psychopathic personality disorder (Decety, Chen, Harenski and Kiehl 2013, 489).

The amygdala is a center for emotional processes in a moral and social direction. Moreover, it is a center for stimuli association which forms connection between emotions, fear in self and the distress and pain of others, forming empathic pathways aligned with moral knowledge and inhibits antisocial behavior. In moral decision contexts and violent visual stimuli, there are lower functioning rates in the amygdala in psychopathic and impulsive aggressive patients. The difference between psychopathy and poor impulse control resides in the lack of empathic traits in the first group when accidental and intentional violence is shown compared to presence of empathic activity in impulsive groups when shown accidental violent stimuli (Dugré, Radua, Carignan-Allard, Dumais, Rubia and Potvin 2020, 170).

The posterior cingulate area is involved in social information processing and moral decision making by linkage with executive and decision-making areas. Disruption in the activities of these linkages have been demonstrated in antisocial behavior patients, when placed in stress-induced contexts. Cognitive and moral judgment disruptions may have only neurobiological reasons or, they may be a consequence of low intellective stimulation during childhood and poor affective development inside the personality levels. a more interesting observation regarding functionality of anterior cingulate area and prefrontal cortex have been assumed to express false emotion, deceit and manipulative traits in psychopaths which are characteristics of their good

interpersonal relations until committing an antisocial act (Jiang, Liu, Liao, Ma, Rong, Tang and Wang 2013, 94).

In adolescents with conduct disorder, fMRI has been the focus of most studies, as the adolescent brain is in continuous development with dynamic endocrinologic, neurochemical and structural modifications. The adolescent brain, as seen in fMRI studies, activates especially impulse responses and bypasses avoidance filters, stimulating executory functions to engage in risky situations. This functioning model is called the triadic model and it consists of prefrontal cortex – the decision hub, the amygdala – the avoidance and control hub and the striatum that represents the approach hub. It seems that emotional triggers, group exposure and adherence and negative external stimuli but also, psychoactive substance usage led to disrupted responses because all stimuli trigger the hyperactive striatum and neglects the hypoactive amygdala, leading the signal directly to the prefrontal area, triggering an active response in an immature structural cortex. Also, fear, risk and intense negative emotions are all processed in an altered way leading to disturbed conduct and poor impulse control in stress contexts. The same triadic model is applicable to adults with addiction problems, the involved structures being active in withdraw symptoms, reward seeking, drug seeking, emotional disorders and behavioral disruption. As such, this is an argument for the predisposition of adolescents for drug abuse (Brown, Benoit, Juhás, Dametto, Tse, MacKay, Sen, Carroll, Hodlevskyy, Silverstone and Dolcos 2015, 124).

An interesting subject in medical literature approaches pedophilia and the intent to find it's neurobiological traits that could help identify, diagnosticate and manage this disorder, which has severe implications in the social and juridical field. There are many classifications of psycho-emotional traits of pedophilia but the mostly it consists of fixated, regressed and sociopathic profiles. The fixated type is characterized by deep emotional involvement as the offender links it's emotional age to the physical age of the child. Although true love is claimed and the offender does not have intentions to harm the child, erotic and physical approach comes as a gratification and a way to create a stronger bond. Usually, the victims are boys but this is not mandatory. The regressive type is characterized by an impulsive reaction to a psycho-emotional stressor, that often appears later in adulthood, during a major affective deficit. Violence is rarely involved as bribes, rewards and seductive techniques are used in order to obtain compliance. Most victims are females and the offenders often feel guilt and remorse related to their own actions but they concentrate on the physical satisfaction in order to cover emotional disturbances. The sociopathic type has most dangerous traits as he lacks remorse and empathy, the physical sexual approach is simplistic with often sadistic elements and he is prone to aggressive behavior, manipulation, threats and intimidation towards its victim in order to achieve compliance. The most plausible motivation for these types of acts is lack of self-esteem, anger and frustration for his personal vulnerabilities and children are chosen mainly because they are easy to dominate physically and mentally than adults (Poeppl, Nitschke, Dombert, Santtila, Greenlee, Osterheider and Mokros 2011, 1662).

In order to understand sexual deviance, fMRI has been used to study normal sexual behavior and to build a schematic neuro-biologic model of sexuality. From a psychological point of view, erotism has cognitive, motivational, emotional and autonomic filters within the central nervous system. Though all of these levels are linked in a variable dynamic, they need to be understood separately. The cognitive hub, where arousal stimuli are filtered, consists of orbitofrontal and superior parietal cortex. The emotional hub, processes the hedonic part of a stimulus and decides the pleasure quality of that stimulus. The second somatosensory and insular region is the hub of the emotional involvement of sexual stimuli. The motivation and desire or reward seeking

hub is represented by the anterior cingulate area and the autonomous art consists in the neuronal linkage of all these hubs with the hypothalamus and the secondary cardiovascular and respiratory effects (Tenbergen, Wittfoth, Frieling, Ponseti, Walter, Walter, Beier, Schiffer and Kruger 2015, 344).

Together, all these relays act in a complex mode, controlling physical, psychological and neurobiological traits of sexual activity. Still, a presumptive balanced network can be described when studying sexual deviance in comparison with healthy individuals. Most of the fMRI studies have revealed deficits in cognitive and emotional linkage in pedophiles. Distorted neural patterns could cause perception disruptions and misinterpretation of a child reactions but also an indifference for consequences at the cognitive level. In case of fixated offenders, there is a lack of coherence when assessing the affective bond with a child and this is what could lead to failure of realistic perception over the situation (Jordan, Fromberger, Laubinger, Dechent and Müller 2014, 10).

Most fMRI studies are describing reduced volumes of amygdala and aberrant activity within the orbitofrontal cortex which would explain the lack of sexual inhibition within these patients. Emotional stimulation during MRI resulted in reduced neuronal activation through affective hubs, especially in the dorsomedial cortex and amygdala. When sexual stimuli were applied, abnormal activity was detected in the cortical brain regions but also in the hypothalamic and midbrain areas, where autonomic traits are activated. The finding is interesting because it would explain why pedophiles are not aroused by adult sexual stimuli but the subject needs further practical exploration. Also, the imbalanced activation between emotional, autonomic and cognitive relays could explain the emotional immaturity and cognitive low inhibitory decision making (Walter, Witzel, Wiebking, Gubka, Rotte, Schiltz, Bermpohl, Tempelmann, Bogerts, Heinze and Northoff 2007, 700).

Conclusions

Assessment of forensic psychiatric patients is in need of more objective argumentation of discernment present antisocial behavior. If in most neuro-pathologies and psychiatric disorders, there are standardized diagnostic, treatment and socio-juridical protocols, for the personality disorders, affective disorders and antisocial behavior, there are still important aspects to be solved. The presence of the discernment does not take the gravity off the medical aspects of these pathologies, although corrective measures can be applied more easily. That is because the sensitive and fine physiopathology involved in these events.

Identification, and medical management of these problems could result in better prevention and a lower rate of recidivism in forensic population. Although research is still needed in this field, we can expect future neuroimaging protocols to be inserted in the forensic psychiatric expertise with better outcome for all organisms involved.

It is clear that for personality disorders and non-organic behavioral disorders, neurobiology and functional brain imaging could set the premises for better treatment, correction of behavioral disruptions and increased quality of social insertion for these people, with less negative impact on the social matrix and law enforcement.

EEG can be used in order to find some of the emotional and behavioral predispositions but the technique per se has low specificity. fMRI could be a strong investigation tool for research and later evaluation protocols and could find specific neuro-biologic disfunctions that could serve as evidence in court and premises for better treatments. No matter the technique, the instruments must observe the patient actively, by appliance of emotional triggers and setting contexts with visual and auditive stimuli.

This would require development of very detailed functional criteria when conducting an exploration like this. Furthermore, psychological test results must coordinate with functional and imaging in order to achieve an objective and doubt-free result. Such standards take time but the newest literature provides many starting grounds for the future of forensic psychiatric expertise.

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