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The neural signature of emotional memories in serial crimes

Philippe Chassy *

Department of Psychology, Liverpool Hope University, UK

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ABSTRACT

Neural plasticity is the process whereby semantic information and emotional responses are stored in neural networks. It is hypothesized that the neural networks built over time to encode the sexual fantasies that motivate serial killers to act should display a unique, detectable activation pattern. The pathological neural watermark hypothesis posits that such networks comprise activation of brain sites that reflect four cognitive components: autobiographical memory, sexual arousal, aggression, and control over aggression. The neural sites performing these cognitive functions have been successfully identified by previous research. The key findings are reviewed to hypothesise the typical pattern of activity that serial killers should display. Through the integration of biological findings into one framework, the neural approach proposed in this paper is in stark contrast with the many theories accounting for serial killers that offer non-medical taxonomies. The pathological neural watermark hypothesis offers a new framework to understand and detect deviant individuals. The technical and legal issues are briefly discussed.

The pathological neural watermark (PNW) hypothesis

The central finding of clinical and investigative studies into serial killers is that sexual crimes are motivated by fantasies [22]. Fantasies can be conceptualised as memory units that elicit high emotional responses when simulated. Primarily, sexual serial killers' actions are driven by the anticipation of the emotional reward that fantasies promise. Because fantasies vary greatly in content and level of violence, many theoreticians over the last decades have postulated various types of taxonomies [13,15,25]. Yet, it has proven difficult to validate these classifications empirically, as the behavioural indicators vary greatly from one killer to the next; accordingly, these classifications do not stand empirical scrutiny [3]. The present paper offers a biological theory that builds upon the neural evidence grounding the pathological nature of the killer. In spite of differences in content, fantasies and their enactments proceed from the same neurobiological principles and processes. As such, the neural trace encoding the fantasy and its enactment should be detectable. It is claimed in this paper that the fantasy motivating sexual crimes, once enacted, leaves a specific, identifiable pattern of brain activity. The present paper identifies the four neural components that constitute such a neural watermark of pathological crime in sexually-motivated serial killers. The proposed theoretical framework offers an integrative view of sexually-motivated serial killers.

Fundamental research in neurobiology has indicated that neural networks form by the creation of new synapses and new connections [14]. The more a given piece of information is processed, the more it calls for restructuration of the neural networks processing it. For example, seminal work on expertise has indicated that London taxi drivers have a bigger hippocampus than non-taxi drivers [19]; that is, by processing spatial information, the memory structure in charge of mapping space increases in size. Similarly, the motor cortex of musicians is denser compared with non-musicians [10]. Emotions become connected with cognitions by the same neural associative process. That is, when an emotion is experienced while processing a stimulus (whether real or imagined), the emotional response becomes associated with it. In experts, like in other individuals, cell assemblies [12] encode the cognitive and emotional components of complex concepts into one single memory structure [6].

The development of sophisticated and detailed fantasies results from the same biological process. For instance, several years before his or her first crime, the fantasy of the serial killer is enriched with details, making it more sophisticated in terms of content and themes. In parallel, the violent nature of the fantasy increases, as does the anticipation of the positive reward. All such cognitive and emotional components are encapsulated within the imagined scenario, which is encoded as a complex memory unit: the fantasy. Next, upon enactment of the fantasy, the cell assembly integrates a fourth component: the neural sites in charge of coding autobiographical memories. The pathological neural watermark hypothesis postulates that all sexually motivated serial killers, regardless

* Address: Liverpool Hope University, HCA Building, Office EW028, Hope Park, L16 9JD, Liverpool, UK.
E-mail address: ChassyP@hope.ac.uk

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of the exact content of the fantasy, will display a specific pattern of activity.

Detailing the four components of the pathological neural watermark (PNW)

Once a fantasy has actually been enacted, it becomes an autobiographical memory; that is, a form of memory characterised by a specific pattern of activation [29]. Neuroimaging evidence demonstrates that retrieving autobiographical memories associated with a specific item uses an identifiable neural network [1]. In addition, autobiographical memories stored at different times display different levels of activation [21], making it possible to organise autobiographical memories chronologically. Equally important for an understanding of serial killers is the fact that distinct sub-regions within the dorsal and ventral medial prefrontal cortex, retrosplenial cortex, and along the parieto-occipital sulcus, preferentially code for events involving the self [28]. Taken together, the research suggests that it is possible to (a) distinguish autobiographical memories from mere imagination, (b) spot the relative time course of memories, and (c) also determine whether they involved the self.

The PNW network also codes the emotions that will be elicited by the sexual fantasy. In fantasy-motivated crimes, emotional responses triggered by exposure to crime-related items will activate the associated fantasy, which in turn should trigger a positive, sexual response. The sexual aspect will be reflected through the increased activity of the reward system, in particular the nucleus accumbens [16]. For psychopathic criminals (see [2] for a review), emotional information processing is poor [7], and arousal is lowered [24]. However, although the brain activity of psychopaths should reflect lower than normal emotional responses, the sexual drive, and thus the neural response associated with it, is still expected to be high. It is crucial to note that, in the context of violence and torture, a positive emotional response is the hallmark of pathologically deviant criminals. The same deviant material would generate highly negative emotional responses in non-deviant individuals. The positive emotional component is key in detecting deviant individuals and thus constitutes an essential component of the PNW. The activation of the nucleus accumbens will likely be accompanied by biomarkers of sexual arousal such as skin conductance and higher heart rate. It is possible that, aware of their pathology, killers will have developed skills in controlling their physiological responses. Yet, even if they are able to hide the sexual pleasure that the anticipation of torture generates, it is likely that they cannot repress the emotional response. Consequently, although these individuals may fool a polygraph, repression of activation in inner regions of the brain is unlikely. The PNW hypothesis thus postulates neural activity in the nucleus accumbens.

The third neural component of the PNW codes the high levels of aggression that the individual experiences in both the anticipation and during the execution of the fantasy. Predatory attacks generate a typical response in the lateral hypothalamus [27]. Should the crime scenes be particularly violent, then the activation of the lateral hypothalamus will reflect the aggression component of the fantasy. Depending on the type of killer, other regions can be expected to be active. Frontal cortical lesions have been implicated in aggressive behaviours [32], as has atrophy in brain regions including the frontopolar and orbitofrontal cortices in violent offenders with Anti-Social Personality Disorders [31]. Similarly, the prefrontal regions and amygdala are implicated in impulsive aggression [23]. These regions are very distinctive from the centres controlling positive emotions and motivational behaviours. The activation of aggression in the presence of items central to a sexual fantasy of murder should generate an intense aggression response. The present framework predicts that deviant individuals will display *both* a positive sexual and a negative aggressive emotional response.

The fourth component of the PNW is the control that the pathological individual exerts over their emotional responses in order to hide their positive feelings in response to deviant items. The long research tradition on emotions has demonstrated that emotional control is revealed through fMRI scanning. Kross et al. [17] observed increased activity in an emotion regulating network when participants attempted to regulate the emotions associated with autobiographical memories. This regulatory network comprises the left prefrontal cortex, the subgenual anterior cingulate and the medial prefrontal cortex. It is crucial to note that the control of emotions, though sometimes indiscernible at the behavioural level, is detectable in fMRI data. Hence, not only will the neural activity reflect the positive emotions felt by the suspect while facing crime evidence, it will also reflect the suspect's attempt to control this response. The neural response showing control is the best evidence that the individual is aware of the deviant nature of his emotions.

The evidence reviewed in the above demonstrates that a serial killer motivated by a sexual fantasy should display a typical neural pattern of activity that would involve autobiographical memory, sexual pleasure, signs of predatory aggression, and emotional control.

Mapping the psychopathological neural watermark

The evidence reviewed indicates that four components constitute the essence of the neural network coding a sexual, pathological fantasy. There is an ample number of studies that have examined the neural correlates of each of these four components. The present article does not aim to review all the studies in these fields of research. Rather, key findings will be highlighted to picture the pattern of activity predicted by the PNW hypothesis. It is important to keep in mind that the PNW hypothesis states that all four components should be active. We would expect activation in the areas of autobiographic retrieval, including those areas involving the self. All neural indicators of positive emotions should also be present (e.g., nucleus accumbens). Similarly, the neural networks underpinning aggression should be active (e.g., hypothalamus). Finally, the involvement of the orbitofrontal cortex in controlling undesirable emotional responses should be present. Table 1 provides a more detailed view of the components that should be active.

Testing the PNW network hypothesis

A Functional Magnetic Resonance Imaging (fMRI) experiment can eventually test the validity of the assumption underlying the

Table 1
Map of regions involved in the PNW.

Component	Region	Function
Aggression	Periaqueductal grey Ventral tegmental of midbrain	Aggression
Positive emotions	Locus ceruleus	Reward of fantasy
Emotional control	Inferior frontal gyrus	Reappraisal of emotions
	Subgenual anterior cingulate	Strategy
	Medial prefrontal cortex Orbitofrontal cortex	
Autobiographical memory	Left medial prefrontal Left angular gyrus Left hippocampus	Retrieval
	Retrosplenial	Involves the Self