



Brain Abnormalities in Murderers Indicated by Positron Emission Tomography

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Murderers who plead not guilty by reason of insanity (NGRI) are thought to have brain dysfunction however, there have been no previous studies reporting direct measures of both cortical and subcortical brain functioning in this specific group. Positron emission tomography (PET) brain imaging was conducted on 41 murderers pleading NGRI and 41 control subjects. Murderers were characterised by reduced glucose metabolism in the prefrontal cortex, superior parietal gyrus, left angular gyrus, and the corpus callosum. There were also abnormal asymmetries of activity (left hemisphere lower than right) in the amygdala, thalamus and medial temporal lobe. These findings provide initial indications of a network of abnormal cortical and subcortical brain processes that may cause a predisposition to violence in murderers pleading NGRI.

Introduction

It has long been suspected that brain dysfunction can predispose someone to violent behaviour. Whilst previous studies have shown that violent offenders have poorer brain functioning than normal control subjects, it has not yet been possible to localise which specific brain areas are dysfunctional. However, past research which looks at criminals with brain injuries does provide clues as to which areas of the brain are associated with violence and so we can expect the following areas to be dysfunctional in murderers; the prefrontal cortex, the left angular gyrus, the amygdala, the hippocampus, the hypothalamus and the corpus callosum (which is responsible for coherence between the two hemispheres, and dysfunction of which can cause hemispheric asymmetries of function. Conversely, no dysfunction is expected in other brain areas (e.g. the midbrain, the cerebellum) which have been implicated in other psychiatric condition but have not been related to violence. One particularly important group of violent offenders consists of those who commit murder and plead not guilty by reason of insanity (NGRI). Although it is thought that such individuals have localised brain impairments, there has been no previous brain imaging research on this important population.

Methods

Subjects

The experimental group consisted of 41 subjects tried in the state of California (39 men, 2 women) with a mean age of 34.3 years who had been charged with either murder or manslaughter. Subjects were referred to the University of California to obtain evidence using PET scanning for a NGRI defence or they had been found guilty and were referred to obtain information that may reduce their sentence. Reasons for referral included history of head injury or brain damage. A control group was formed by matching each murderer with a normal subject of the same sex and age who was tested using identical PET imaging procedures in the same laboratory. The mean age of the 41 controls (39 men, 2 women) was 31.7. They had been screened for health with a physical exam, a psychiatric interview and their medical history was checked.

PET Task Procedure

The radioactive tracer (fluorodeoxyglucose) was injected into the the subject and taken up by the brain for a 32 minute period during which the subject completed a continuous performance task (CPT). The subject was then transferred to a PET scanner where the brain was scanned in 10 mm horizontal slices as shown in Figure 1.

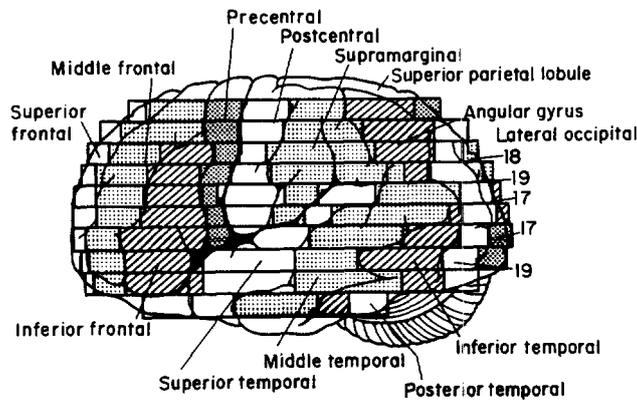


Figure 1. A lateral view of 10 stacked slices showing the prefrontal cortex, and temporal, parietal, and occipital areas.

Results

Cortical Regions

As anticipated, the group of 41 murderers had significantly lower glucose metabolism relative to controls in both the lateral and medial prefrontal cortex in both hemispheres (see Figure 2).

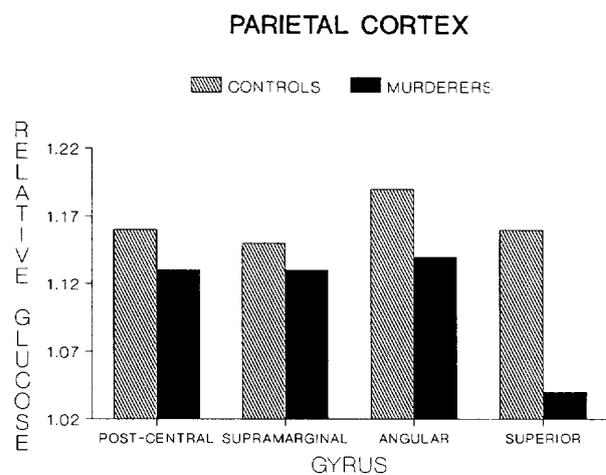
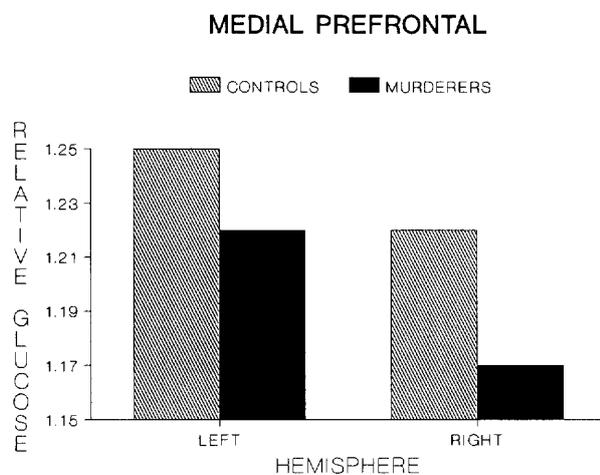
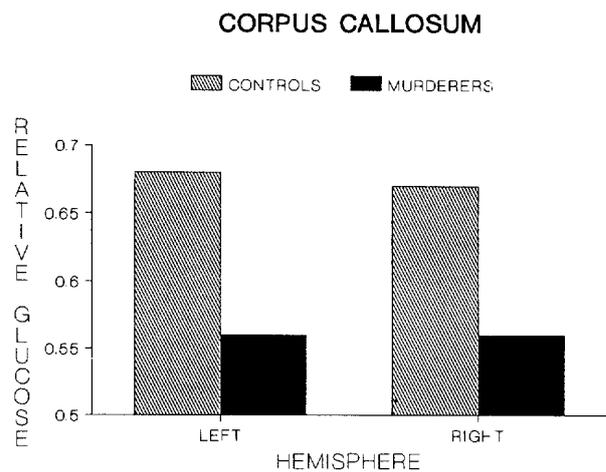
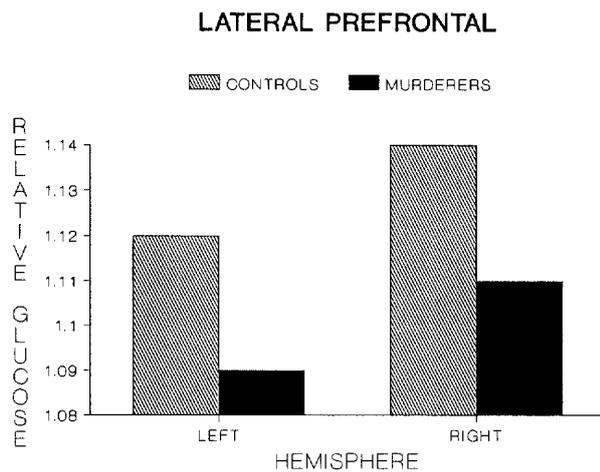


Figure 2. Relative glucose metabolic rates for murderers and controls in the lateral and medial prefrontal cortex.

Figure 3. Relative glucose metabolic rates for murderers and controls in the corpus callosum and the parietal cortex.

Murderers had significantly lower parietal glucose metabolism than controls, especially in the left angular gyrus. As indicated in Figure 3, murderers had significantly lower glucose especially in the left and right superior parietal gyri. Murderers were identical to controls on temporal lobe glucose metabolism. Murderers were found to show significantly *higher* occipital lobe glucose metabolism than controls.

Subcortical Regions

Murderers have bilaterally lower glucose metabolism in the corpus callosum than controls. Murderers showed an abnormal asymmetry of activity with reduced left and increased right amygdala activity relative to controls. Murderers showed an abnormal asymmetry of activity with reduced left and increased right activity in the hippocampus. Murderers showed an abnormal asymmetry consisting of relatively greater right thalamic activity.

As predicted, there were no significant differences for the amount of midbrain and cerebellum activity between murderers and controls.

Groups did not differ on any aspect of behavioural performance on the CPT.

Discussion

The key findings from this study are that murderers pleading NGRI are characterised by;

- reduced glucose metabolism in the prefrontal cortex, the parietal cortex, and the corpus callosum.
- abnormal asymmetries of activity (left hemisphere lower than right) in the amygdala, thalamus, and the hippocampus.

Biosocial Pathways from Brain Deficits to Violence

A key question is how these multisite deficits can translate into violence via neuropsychological, cognitive and social pathways. Regarding prefrontal deficits, damage to this brain region can result in impulsivity, loss of self-control, immaturity, and the inability to modify behaviour, which in turn facilitates aggressive behaviour.

The amygdala, hippocampus, and prefrontal cortex make up part of the limbic system which governs the expression of emotion, while the thalamus relays inputs from subcortical structures to the prefrontal cortex. The hippocampal formation is thought to modulate aggression through its action on the lateral hypothalamus and together with the prefrontal cortex, forms the neurobiological basis of Gray's Behavioural Inhibition System, which is theorised to be dysfunctional in violent and psychopathic individuals.

The hippocampus, amygdala, and thalamus are also important for learning, memory and attention; abnormalities in their functioning may relate to deficits in forming conditioned emotional responses and a failure to learn from experience, a trait which is often displayed by violent offenders. The amygdala additionally plays a role in the recognition of emotional and socially significant stimuli, with destruction of the amygdala in animals resulting in a lack of fear and in humans in a reduction in autonomic arousal; thus abnormalities in the amygdala could be relevant to a fearlessness theory of violence based on psychophysiological findings of reduced autonomic arousal in offenders.

The parietal cortex is involved in the integration of sensory input and the formation of abstract concepts and may contribute to the deficits in cognitive and social information processing observed in violent offenders. If the angular gyrus is damaged or experiences a reduction in glucose metabolism, the individual may experience reduced verbal, arithmetic and reading ability. Such cognitive dysfunctions could predispose to educational and occupational failure, which in turn could predispose to crime and violence. Learning deficits have been found to be common in violent offenders who also have low verbal IQs.

This study provides the first direct evidence supporting the long-held notion that dysfunction in the corpus callosum may cause a predisposition to violence. Callosal dysfunction and the resulting

lack of inter hemispheric integration could contribute to the abnormal asymmetries of function and reduced integration previously observed in antisocial and violent groups. Another potential implication of poor inter-hemispheric transfer is that the right hemisphere, which is involved in the generation of negative emotions, may experience less regulation and control by the inhibitory processes of the left hemisphere, a factor that may contribute to the expression of violence in predisposed individuals. Rats who are stressed during their early life show increased activity in the right hemisphere when killing mice. Severing the corpus callosum in rats leads to an increase in mice-killing, indicating that the left hemisphere acts to inhibit the right hemisphere-mediated killing via an intact corpus callosum. It has been observed that split-brain patients experience poor emotional expression and an inability to grasp the long-term implications of a situation. These traits are commonly found in violent offenders, further implicating the role of the corpus callosum in inhibiting aggression. However it should be noted that findings from animal research cannot be directly extrapolated to humans. Furthermore, callosal dysfunction itself is unlikely to cause aggression; instead it may contribute to violence in those with limbic and cortical abnormalities.

The findings of this study suggest that the neural processes underlying violence are complex and cannot be reduced to single brain mechanisms causing violence in a direct causal fashion. Instead, violent behaviour probably involves disruption of network of multiple interacting brain mechanisms that predispose to violence in the presence of other social, environmental, and psychological predispositions. Nevertheless, attempts to 'connect' findings from the individual brain sites in this study must proceed cautiously, because there are brain mechanisms relevant to aggression (e.g. the hypothalamus) that could not be imaged in this study. For this reason, this study cannot provide a complete account of the neurophysiology of violence in this specific and selected subgroup of violent offenders, although it is felt that it both provides evidence that murderers pleading NGRI have different brain functioning compared to controls, and also gives initial suggestions as to which specific neural processes may predispose to their violent behaviour.

Conclusions

First, it is important to document that these findings cannot be taken to demonstrate that violence is determined by biology alone; clearly, social, psychological, cultural, and situational factors also play important roles in predisposing to violence. Second, these data do not demonstrate that murderers pleading NGRI are not responsible for their actions, nor do they demonstrate that PET can be used as a diagnostic technique. Third, these findings do not establish causal link between brain dysfunction and violence. Fourth, findings cannot be generalised at the present date from NGRI murder cases to other types of violent offenders. What these findings do document is that as a group, murderers pleading NGRI have statistically significant differences in glucose metabolism in certain brain regions compared to control subjects. They also suggest that reduced activity in the prefrontal, parietal, and callosal regions of the brain, together with abnormal asymmetries of activity in the amygdala, thalamus, and hippocampus, may be one of many predispositions toward violence in this specific group. As with all initial findings, future independent replication, refinement, and extension are greatly needed.