UNIVERSITY OF PENNSYLVANIA HEALTH SYSTEM

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INTEGRATIVE BRAIN BEHAVIOR EVALUATION

PATIENT'S NAME:	Lisa Marie Montgomery
DATE OF BIRTH:	February 27, 1968
AGE:	39
DATE OF REPORT:	4/3/2007
INTEGRATION:	Ruben C. Gur, PhD
REFERRED BY:	FREDERICK A. DUCHARDT, JR., ESQ.

Background:

Ms. Lisa Montgomery's attorney asked me to form an opinion as to whether Lisa suffers from any mental abnormality, injury or illness. He also asked whether, if such abnormality, injury or illness exists, it impacts upon her functioning in a way that is germane to this case.

To form my opinion, I have reviewed background materials including hospital and school records, a summary of Ms. Montgomery's background, and police records related to the crime. I have then requested a comprehensive neuropsychological evaluation as well as functional and structural neuroimaging studies, which were needed to answer the referral question. The neuropsychological evaluation was performed by Dr. Rob Fucetola, Ph.D., ABPP-CN, Chief of Clinical Neuropsychology and Associate Professor of Neurology, Washington University School of Medicine. The MRI and PET studies were performed at the University of Pennsylvania Medical Center, under my supervision. With help from Faculty and postdoctoral Fellows at our center, I have analyzed and verified the results of the neuropsychological testing, the structural imaging study (MRI), and the functional imaging study (PET). Here I will highlight the main findings and offer an opinion on whether Ms. Montgomery has brain abnormalities that could relate to her behavior.

Major findings

Notable from record review are several instances of head injuries that could lead to brain dysfunction. On January 19, 1998, Lisa was treated for a cut to the left parietal area of her head, which she sustained as the result of her hitting her head during a car accident. On September 14, 1998, Lisa was treated after a car accident in which she hit her forehead on the windshield of her car. On June 21, 1999, while playing on a trampoline with one of her children, Lisa was hit in the back of the head. She was treated at an emergency room after she reported feeling confused and disoriented. Lisa also has a history of intense, migraine-type headaches. She has, on occasion, sought hospital help for these headaches. Her history of sexual abuse could also be a stressor contributing to brain dysfunction, s recent evidence suggests.

Ms. Montgomery's neuropsychological test performance clearly indicated that she has put forth her best efforts and was not malingering. We have applied the "Behavioral Imaging" algorithm[1] to further establish the potential localization of brain damage based on the neuropsychological test scores. The process for this schematic representation of clinical data has been demonstrated to be clinically reliable and stable in defining and localizing affected areas of neurological impairment. The technology permits clinical professionals to effectively determine the regional distribution of deficits identified in standard neuropsychological tests, and thus assist in the diagnosis, treatment, and study a variety of brain disorders, including Parkinson's Disease, Alzheimer's Disease, Schizophrenia, and neurodevelopmental disorders. The image is a true topographic display of the neuropsychological data in reference to the dysfunctional areas and severity of impairment. The image in **Figure 1** depicts three views of Ms. Montgomery's brain from the left (top left panel), the right (lower left panel) and the top (right panel, with the front of the brain oriented toward the top of the panel). The scale in the lower right of the image represents functional capacity relative to the most intact ability. It is expressed as standard deviations away from normal. Ms. Montgomery's BI indicates overall high level of performance (all z-score values on the scale are positive), she's a smart person. However, there is relative weakness in the functioning of right medial structures, starting with right orbito-frontal function, related to impulse control, and extending to the right parietal juncture, which relates to personal integration and sense of self. Such deficits could be more severe than reflected in the neuropsychological measures, which focus on cognitive domains. They indicate a more thorough evaluation of personality disturbances. The pattern of deficits is consistent with traumatic head injury.

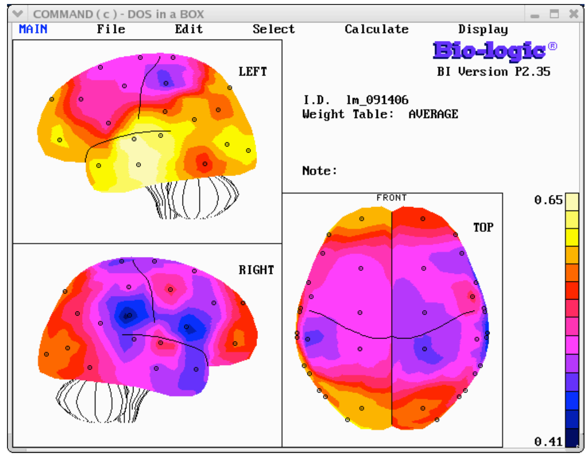

Figure 1. The behavioral image of Ms. Montgomery

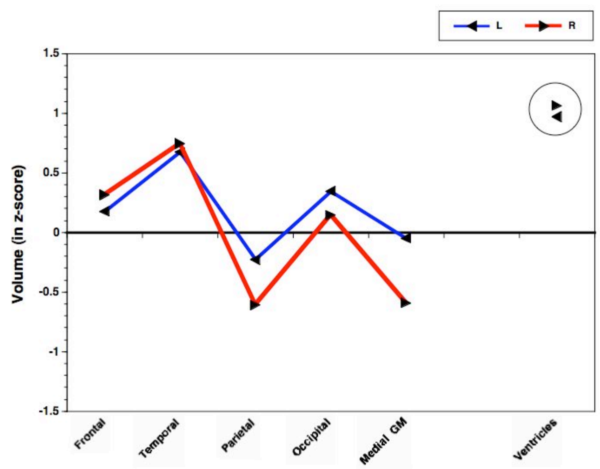

Figure 2. Volumetric MRI results for Ms. Montgomery

[1] Gur RC, Trivedi SS, Saykin AJ, Gur RE. "Behavioral imaging" - a procedure for analysis and display of neuropsychological test scores: I. Construction of algorithm and initial clinical evaluation. Neuropsychiatry, Neuropsychology and Behavioral Neurology, 1988, 1, 53-60; Gur RC, Saykin AJ, Blonder LX, Gur RE. "Behavioral imaging": II. Application of the quantitative algorithm to hypothesis testing in a population of hemiparkinsonian patients. Neuropsychiatry, Neuropsychology and Behavioral Neurology, 1988, 1, 87-96; Gur RC, Saykin AJ, Benton A, Kaplan E, Levin H, Kester DB, Gur RE. "Behavioral imaging": III. Inter-rater agreement and reliability of weightings. Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 1990, 3, 113-124; Blonder LX, Gur RE, Gur RC, Saykin AJ, Hurtig HI. "Neuropsychological functioning in hemiparkinsonism." Brain and Cognition, 1989, 9, 177-190.

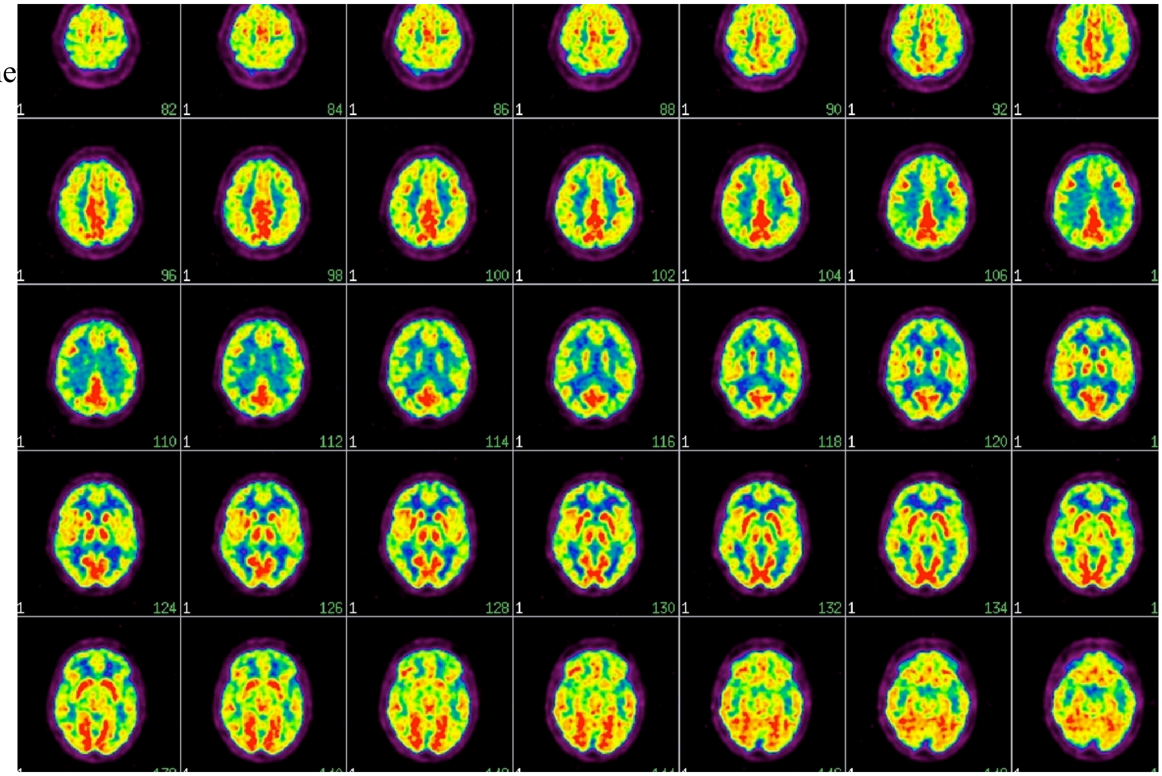

Figure 3. The PET scan images of Ms. Montgomery (transaxial views).

The magnetic resonance (MR) images of Ms. Montgomery were examined via delineation of 92 regions of interest (ROI), which was assisted by a semi-automated template-warping algorithm.[2] This analysis revealed that Ms. Montgomery has an unusual brain structure. In order to localize Ms. Montgomery's structural abnormalities, we examined the volumes of different brain compartments. The results (**Figure 2**) revealed that while Ms. Montgomery has an overall normal brain volume, there are also some distinct abnormalities with lower than normal volumes in right parietal lobes, as well as right medial gray matter. Most pronounced, however, is bilateral increase in ventricular volume, which is more that a standard deviation higher than average. Reduced volume of the right parietal and medial regions is consistent with the results of the neuropsychological testing. Right parietal dysfunction manifests itself behaviorally in loss of sense of self, difficulties in emotion processing, attentional neglect, and depressed or flat affect.

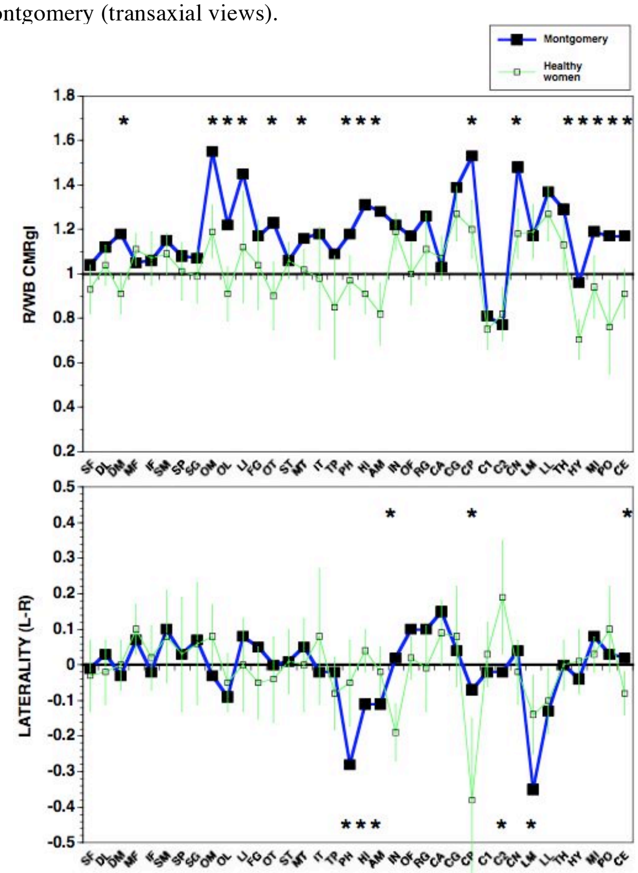

Figure 4. Quantitative PET data

The positron emission tomography (PET) study, which examined the regional distribution of glucose metabolic activity using fluorine-18 labeled deoxyglucose (FDG), was read clinically as showing increased limbic relative to frontal activity. These abnormalities are observable by inspection of the PET scans (**Figure 3**). Consistent with this reading, the quantitative analysis of count rates relative to whole brain indicated substantial and significant relative increase in the entire limbic system including inferior temporal, temporal pole, parahippocampal regions, as well as hippocampus, amygdala and posterior cingulate regions (**Figure 4, top panel**). Notably,

[2] D. Shen, C. Davatzikos, IEEE Transactions on Medical Imaging 21, 1421-1439 (November, 2002).

medial dorsal aspect of the frontal lobe and some occipital regions likewise show elevated activity as well as thalamus, hypothalamus, brain stem and cerebellum. Examination of the laterality indices (**Figure 4, bottom panel**) indicates that the limbic activity is most elevated in right parahippocampus, hippocampus and amygdala. These findings indicate abnormalities in brain glucose utilization in medial structures, most pronounced in right limbic regions. These regions are important for emotion processing and memory formation. The rather striking elevation in cerebral glucose utilization in thalamus, hypothalamus and the midbrain, pons and cerebellum may relate to high vulnerability to disorders with visceral sensory activation.

<u>Summary and Conclusions</u>

The current findings consistently indicate brain dysfunction in an individual with an otherwise normal intellectual functioning. Behavioral and neurobiological data indicate that Ms. Montgomery is struggling with genuine deficits that, by profile and severity, are consistent with limbic, hypothlamic and parietal lobe damage. The neuropsychological evaluation indicates relative deficits in functions related to mesial brain structures, more on the right. Consistent with these findings, the quantitative MRI studies show reduced brain volume in right parietal and medial gray matter, and abnormally high ventricular volume consistent with loss of tissue in medial brain structures. PET results showed abnormally increased metabolic activity in nearly all temporolimbic structures as well as in some frontal and motor regions and thalamus. The abnormally increased activity in hippocampus and parahippocampal regions, as well as the amygdala, is more pronounced on the right. This pattern indicates increased vulnerability to impulsive behavior. The increased hypothalamic and related activation is potentially a source of vulnerability to pseudocyesis (by history).The combination of reduced volume and increased glucose metabolism in the right suggests compensatory processes. Right hemisphere compensatory activation has been related to dissociative states.

While the etiology of these abnormalities is uncertain, the results of all the testing, including the neuropsychological evaluation and structural and functional neuroimaging studies, are quite consistent with a history of head injuries or a neurodevelopmental brain disorder, possibly exacerbated by post-traumatic stress disorder (PTSD) as a result of childhood sexual abuse. By history, the anatomic abnormalities could also relate to poor prenatal conditions.

The brain abnormalities documented in the neuropsychological and the structural and functional neuroimging studies provide evidence that Ms. Montgomery's actions have been influenced by a compromised neural substrate. Her brain is neither structurally nor functionally sound, and the damage is in areas that are needed for integrated behavior under full conscious control.

All the opinions contained herein are stated to a reasonable degree of scientific certainty. I hope this summary is helpful. Please let me know if you have questions or need further clarifications.

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Ruben C. Gur, PhD
Professor of Neuropsychology

Abbreviations in PET Figures:

SF = Superior Frontal; DL = Dorsal Prefrontal – Lateral; DM = Dorsal Prefrontal – Medial; MF = Mid–Frontal; IF = Inferior Frontal; SM = Sensorimotor; SP = Superior Parietal; SG = Supramarginal Gyrus; OL = Occipital cortex, Lateral ; OM = Occipital cortex, Medial; LI = Lingual Gyrus; FG = Fusiform Gyrus; OT = Occipital Temporal; ST = Superior Temporal; MT = Mid–Temporal; IT = Inferior Temporal; TP = Temporal Pole; PH = Parahippocampal Gyrus; HI = Hippocampus; AM = Amygdala; IN = Insula; OF = Orbital Frontal; RG = Rectal Gyrus; CA = Cingulate Gyrus – Anterior; CG = Cingulate Gyrus - genu; CP = Cingulate Gyrus – Posterior; C1 = Corpus Callosum – Anterior; C2 = Corpus Callosum – Posterior; CN = Caudate Nucleus; LM = Lenticular – Medial [Globus Pallidus]; LL = Lenticular – Lateral [Putamen]; TH = Thalamus; HY=Hypothalamus; MI = Midbrain; PO = Pons; CE = Cerebellum.