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A Perspective on the Potential Role of Neuroscience in the Court

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A PERSPECTIVE ON THE POTENTIAL ROLE OF NEUROSCIENCE IN THE COURT

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INTRODUCTION

This Article presents some lessons learned while offering expert testimony on neuroscience in courts. As a biomedical investigator participating in cutting-edge research with clinical and mentoring responsibilities, Dr. Ruben Gur, Ph.D., became involved in court proceedings rather late in his career. Based on the success of Dr. Gur and other research investigators of his generation, who developed and validated advanced methods for linking brain structure and function to behavior, neuroscience findings and procedures became relevant to multiple legal issues, especially related to culpability and mitigation. Dr. Gur found himself being asked to opine in cases where he could contribute expertise on neuropsychological testing and structural and functional neuroimaging. Most of his medical-legal consulting experience has been in capital cases because of the elevated legal requirement for thorough mitigation investigations in such cases,[1] and his limited availability due to his busy schedule as a full-time professor and research investigator who runs the Brain and Behavior Lab at the University of Pennsylvania ("Penn"). Courtroom testimony, however, has not been a topic of his research and so he has not published extensively on the issues in peer-reviewed literature.

Dr. Gur's specific experience has been providing testimony as to the potential behavioral effects of brain damage in certain regions of the brain.

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1. *See, e.g.*, Rompilla v. Beard, 545 U.S. 374, 377, 390 (2005) (finding defense counsel in a capital case ineffective for failing to adequately investigate mitigating evidence despite having interviewed the defendants' family and friends and having obtained mental health examinations and reports); Wiggins v. Smith, 539 U.S. 510, 536–38 (2003) (finding defense counsel ineffective for failing to present mitigating evidence in a capital case); Williams v. Taylor, 529 U.S. 362, 390–91 (2000) (finding defense counsel in a capital case ineffective for failing to timely investigate mitigating evidence).

Although the law has a long history with testimony on this subject,[2] the slow process of creating legislation and establishing precedent leaves the law behind the rapid pace of scientific innovation. The law has yet to fully absorb the kind of rigorously tested brain behavior science that is increasingly available. It is no surprise that there are opponents of introducing neuroscience testimony, either because they feel it is flawed in some way (methodologically or as applied) or because they feel that its probative value is outweighed by the potential to unduly influence the trier of fact. Still, the field is rapidly evolving, and multimodal integration will pave the way for additional, heretofore unimaginable mechanistic insights. Ironically, a potential hurdle for the neuroscientist involved in expert testimony is that, while more precise and reliable, data will become increasingly more difficult to understand and, therefore, explain. It has become hard to find experts who can speak knowledgeably about behavior and the range of neuroimaging parameters relevant to its interpretation.[3]

To provide a framework for appreciating the contribution that neuroscience can make to the courts, this Article begins in Part I with a brief historical overview of the evolution of behavioral neuroscience to the point of becoming relevant in court. Next, Part II presents a brief account of how Dr. Ruben Gur became involved in litigation, primarily offering neuroscience-based expertise as mitigation evidence in capital cases. Part II also briefly describes the typical analytical processes[4] used by Dr. Gur and other neuroscience experts he consults with when responding to requests for expert analysis. Part III then outlines some of the lessons learned from testifying as a neuroscience expert. Finally, Part IV concludes with a discussion of some of the objections raised against the use of neuroscience testimony in the courtroom.

I. LINKING THE BRAIN TO BEHAVIOR AND THE LEGAL RELEVANCE OF NEUROSCIENTIFIC EVIDENCE

The story of the application of neuroscience to legal matters cannot be told without briefly tracing the history of neuroscientific methods. Accordingly, Part I.A traces the history of neuroscience and Part I.B explores the emergence of modern methodologies, technologies, and diagnostic tools employed by neuroscientists. Then, Part I.C briefly discusses neuroscience's recent transition to a useful court apparatus.

2. *See, e.g.*, Edward E. Mayer, *Prefrontal Lobotomy and the Courts*, 38 J. CRIM. L. & CRIMINOLOGY 576 (1948) (discussing court testimony on brain damage).

3. For example, some experts lack the expertise to replicate an opposing expert's findings and will need to consult with additional experts.

4. Our typical analytical processes are reviewed in greater detail elsewhere, and much of what we describe here can be found in a recent publication by Ruben and Oren Gur. *See generally* Ruben C. Gur & Oren M. Gur, *Linking Brain and Behavioral Measures in the Medical-Legal Context*, *in* THE EVOLUTION OF FORENSIC PSYCHIATRY: HISTORY, CURRENT DEVELOPMENTS, FUTURE DIRECTIONS 295 (Robert L. Sadoff ed., 2015).

A. A Brief History of Neuroscience

That the brain is the sole organ that regulates cognition and behavior is a relatively recent discovery in the history of civilization. The ancient Greeks believed that different organs were responsible for aspects of behavior. For example, they thought that courage arose from the heart, reason from the head, and "base qualities" from the stomach.[5] It took another fourteen centuries before Albertus Magnus concluded that the brain controlled behavior. However, he (and others) thought that the "action" was in the three ventricles[6]: The first ventricle processed the five senses, passing images to the middle ventricle that did the reasoning before transferring the results to the third ventricle for memorization and storage.[7] René Descartes was first to articulate the idea that the seat of the soul was in brain tissue.[8] Descartes had difficulty, however, reconciling his knowledge of brain anatomy and his Christian faith, as the soul is considered unitary—deserving of salvation or punishment—yet the brain is clearly separated into two hemispheres.[9] To reconcile this contradiction, he concluded that the one brain structure that does not have two hemispheres, the pineal gland, must be the seat of the soul.[10]

Subsequent investigators accepted the notion that cognition and behavior are products of brain function, but the relation between brain processes and behavior was an enigma. Phrenology developed as a discipline that further influenced scientific thinking about the brain and behavior. Early efforts were restricted by the tools available to investigate the brain, and, to this day, our ability to link brain function to behavior is limited by technology and methodology. Lacking the tools to investigate the brain itself, phrenologists studied the head and attempted to correlate size and shape of different portions of the skull with human "faculties."[11] For example, large foreheads were said to be associated with intellectual abilities.[12] Phrenology was never accepted by the mainstream of science, and the whole idea of localizing behavioral domains in brain regions became tarnished.[13] The experience with phrenology may have generated negative

5. *See* STANLEY FINGER, ORIGINS OF NEUROSCIENCE: A HISTORY OF EXPLORATIONS INTO BRAIN FUNCTION 14 (1994).

6. *Id.* at 18–19.

7. *See* 1 FRANK SPENCER, HISTORY OF PHYSICAL ANTHROPOLOGY: AN ENCYCLOPEDIA 424 (1997).

8. *See* RENÉ DESCARTES, TREATISE OF MAN 36–37 (Thomas Steele Hall trans., 1972) (1664) [hereinafter DESCARTES, TREATISE OF MAN]; René Descartes, *The Passions of the Soul*, *in* THE PASSIONS OF THE SOUL AND OTHER LATE PHILOSOPHICAL WRITINGS 191, 195–97 (Michael Moriarty trans., 2015) [hereinafter Descartes, *The Passions of the Soul*].

9. *See generally* DESCARTES, TREATISE OF MAN, *supra* note 8; Descartes, *Passions of the Soul*, *supra* note 8.

10. *See generally* DESCARTES, TREATISE OF MAN, *supra* note 8; Descartes, *Passions of the Soul*, *supra* note 8.

11. NICOLE RAFTER, THE CRIMINAL BRAIN: UNDERSTANDING BIOLOGICAL THEORIES OF CRIME 40–42 (1939).

12. *See id.* at 44, 87.

13. *See id.* at 61.

attitudes toward efforts to localize cognitive "faculties" in specific brain regions.

This was the backdrop for the work of a nineteenth-century French neuroscientist, Pierre Paul Broca, who reasoned that the criticism against phrenologists may have been too focused on the type of "faculties" they associated with specific brain regions.[14] He argued that the principle that different brain regions control aspects of behavior might still hold true, even if previous efforts had failed to systematically examine the connection between specific brain regions and important human faculties, such as speech.[15] Broca maintained that speech was both unique and important and should have a localizable brain structure to support it.[16] He proposed a methodology for scientifically establishing such links between the brain and behavior.[17] It involved a careful study of people who suffered damage to their brain, outlining and documenting their behavioral deficits, and then finding out which brain regions were damaged by detailed autopsy.[18]

Broca's focus on speech led him to study several patients with severe speech deficits who were not otherwise demented. One of the most influential cases he studied was that of Monsieur Lelong, an elderly gentleman who suffered a sudden onset of speech loss.[19] He used only seven words: "yes," "no," "one," "two," "three," "Lelong," and "*toujour*" (the French word for "always").[20] Broca demonstrated, however, that Lelong understood speech and applied his limited vocabulary appropriately: he used "one" for the number "one," "two" for the number "two," "three" for any number larger than two, "yes" for affirmation, "no" for negation, and "*toujour*" for all other words.[21] An autopsy revealed a large lesion in the third frontal convolution of the left hemisphere.[22] Broca published his findings in 1861, thereby establishing the field of neuropsychology.[23]

Broca's paradigm became recognized as the "clinical-pathological correlation" method and has contributed much of what we know today about brain behavior relations. In 1874, Carl Wernicke expanded on Broca's findings and documented that lesions more posterior to what became known as Broca's area "were associated with relatively preserved speech output, but diminished capacity to comprehend speech."[24] Links between brain abnormalities and emotional behavior were first established in 1914 by Joseph Babinski, who reported on a series of sixteen patients with significant brain damage manifested behaviorally by denial of symptoms (anosognosia), and even unusual jollity about having these

14. *See* Gur & Gur, *supra* note 4, at 296.
15. *See id.*
16. *See id.*
17. *See id.*
18. *See id.*
19. *See id.*
20. *See id.*
21. *See id.*
22. *See id.*
23. *See id.*
24. *See id.*

symptoms (anosodiaphoria).[25] Notably, all these patients had major lesions in the right hemisphere.[26] The British neurosurgeon Samuel Alexander Kinnier Wilson described a patient who laughed incessantly, to the point of not being able to eat.[27] Wilson had to overcome the danger of dehydration by sitting at the patient's bedside and yawning deliberately, which induced the patient to yawn long enough for the nurse to feed him.[28] This patient had bilateral brain damage.[29] Other investigators, such as John Hughlings Jackson in 1932, reported that lesions in the right hemisphere produced deficits in spatial abilities.[30] The literature on mood changes associated with regional brain damage was summarized by Harold Sackeim et al., who concluded that right hemispheric lesions were associated with positive symptoms of jocular affect, while left hemispheric lesions were associated with release of negative affect.[31] It is now indisputable that both cognitive and emotional processing are disrupted in patients with brain lesions, and different behavioral domains are affected depending on the location and nature of brain damage.[32]

The most dramatic demonstrations of specific regional control of behavior by the brain were produced in the middle of the twentieth century by the Canadian neurosurgeon Roger Penfield in his studies of brain stimulation.[33] Penfield performed surgery on patients with temporal lobe epilepsy while they were awake and could therefore observe the effects of stimulating different brain regions on behavior.[34] He found that he could consistently induce patients to lift an arm or a finger by stimulating specific regions in the contralateral hemisphere, and he was able to methodically map the entire motor system in this way.[35] Penfield discovered a virtual

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25. *See id.*

26. *See id.*

27. *See* S.A. Kinnier Wilson, *Some Problems in Neurology* (pt. 2), 4 J. NEUROLOGY & PSYCHOPATHOLOGY 299, 302 (1924).

28. *See id.*

29. *See id.*

30. *See generally* 2 JOHN HUGHLINGS JACKSON, *On Affections of Speech from Disease of the Brain*, *in* SELECTED WRITINGS OF JOHN HUGHLINGS JACKSON 115–204 (James Taylor ed., 1958).

31. *See* Harold A. Sackeim et al., *Hemispheric Asymmetry in the Expression of Positive and Negative Emotions: Neurological Evidence*, 39 ARCHIVES NEUROLOGY 210, 210, 215 (1982). It is noteworthy that brain lesions can produce both "negative" symptoms and "positive" symptoms. Negative symptoms are behavioral deficits, such as fluent speech or memory that patients can no longer perform at normative levels. Positive symptoms are new behaviors, such as jocular, aggressive, or depressed mood, which may emerge because of damage to regions that inhibit or regulate such behaviors.

32. *See generally* Richard J. Davidson et al., *Emotion, Plasticity, Context, and Regulation: Perspectives from Affective Neuroscience*, 126 PSYCHOL. BULL. 890 (2000).

33. *See generally* WILDER PENFIELD, THE MYSTERY OF THE MIND: A CRITICAL STUDY OF CONSCIOUSNESS AND THE HUMAN BRAIN (1975) [hereinafter PENFIELD, THE MYSTERY OF THE MIND]; WILDER PENFIELD & HERBERT JASPER, EPILEPSY AND THE FUNCTIONAL ANATOMY OF THE HUMAN BRAIN (1954); Wilder Penfield, *Memory Mechanisms*, 67 A.M.A. ARCHIVES NEUROLOGY & PSYCHIATRY 178 (1952).

34. *See generally* PENFIELD, THE MYSTERY OF THE MIND, *supra* note 33.

35. *See id.*

"homunculus" (meaning "a little man" in Latin)[36] along the fissure that separates the frontal lobe from the parietal lobe.[37] The entire human body was represented, and each limb (e.g., individual fingers) could be activated by an electrical pulse administered to specific contralateral locations of the brain.[38] A parallel "receptive" homunculus was demonstrated in the parietal side of the same fissure, where stimulation would lead to sensations from corresponding body parts.[39] Thus, one spot, when stimulated, would make the patient feel like his left index finger was being touched, another spot would cause the sensation that the left thumb was touched, and yet another spot would generate the sensation of being touched on the face.[40] Stimulating other parts of the brain could induce or arrest speech.[41]

In addition to helping map behavior into specific brain regions with a powerful experimental paradigm, Penfield's work has another specific relevance to the medical-legal context. Considering the importance of free will in legal culpability, it is noteworthy that during Penfield's procedures, when patients were asked why they moved their arm or finger, or why they began or ceased talking, they typically reported a subjective feeling that such action was their wish.[42] Therefore, patients invariably perceived actions induced by electrical stimulation, which they were obviously not controlling, as being under their voluntary control.[43]

As evidence was accumulating on links between specific types of brain damage and behavioral deficits, the need arose to gauge the probability of brain damage in cases when it was not clear whether aberrations were caused by such damage or by other factors. Most brain disorders do not produce effects as dramatic as those seen in Lelong,[44] and it is not always clear whether a particular level of performance on a specific behavioral domain reflects deviation from what is normative for that individual or for people like him who do not suffer from brain damage. For instance, someone might be a poor performer in the eyes of a physician, when in fact her performance level is within what can be expected of someone of similar educational and socioeconomic background.

B. The Emergence of Modern Methodologies and Technologies in Neuroscience Research

Fortunately, the turn of the twentieth century, which introduced neurological evidence linking behavioral domains to regional brain

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36. *See Homunculus*, MERRIAM-WEBSTER'S DICTIONARY, http://www.merriam-webster.com/dictionary/homunculus (last visited Oct. 16, 2016) [https://perma.cc/X9ZX-CM4V].

37. *See* RENÉ RIEDL & PIERRE-MAJORIQUE LÉGER, FUNDAMENTALS OF NEUROIS: INFORMATION SYSTEMS AND THE BRAIN 35 (2016).

38. *See generally* PENFIELD, THE MYSTERY OF THE MIND, *supra* note 33.

39. *See generally* PENFIELD & JASPER, *supra* note 33.

40. *See generally* PENFIELD, THE MYSTERY OF THE MIND, *supra* note 33.

41. *See generally id.*

42. *See generally id.*

43. *See generally id.*

44. *See supra* notes 19–21 and accompanying text.

function, also saw revolutionary progress in psychometric theory and methodology,[45] which allowed for the development of reliable measurement of behavioral performance. Psychologists have developed tests that measure overall intellectual capacity as well as specific domains of cognition, and psychologists who worked with neurological and neuropsychiatric patients—soon to be called "neuropsychologists"—began to develop measures that could help diagnose brain dysfunction.[46] "For example, to measure verbal output fluency, [neuro]psychologists have developed standardized tests where someone is given a limited amount of time to produce as many words as possible that start with a certain letter."[47] Such tests would not be necessary for detecting severe deficits in patients like Lelong, who could not produce more than a dozen or so words even if given an hour, but they could detect smaller lesions in the same area in which damage obliterated Lelong's speech capacity.[48] Applying such verbal fluency tests—such as asking the patient to say in under one minute as many words as possible starting with a specific letter—to patients proved sensitive to the presence of left frontotemporal lesions.[49] Similarly, tests of memory proved sensitive to temporal-limbic anomalies,[50] and tests of executive functions such as concept formation and set shifting proved sensitive to frontal lobe damage.[51] Leading neuropsychologists, such as Dr. Arthur Benton and Dr. Edith Kaplan, have compiled such tests into assessment tools—neuropsychological batteries—that are incorporated into the diagnostic workups in a range of disorders that are associated with behavioral abnormalities and cognitive deficits.[52] Research and clinical work using this methodology helped solidify the field of neuropsychology, and it is now a recognized subspecialty of the American Board of Professional Psychology (ABPP).[53] Neuropsychology has become the discipline at the intersection of linking behavioral domains to the functioning of brain systems.

Progress in neuropsychology was nevertheless hampered by the need to rely on correlating behavioral measures with brain abnormalities that are putatively responsible for behavioral deficits. Neuropsychologists could

45. *See, e.g.*, Charles Spearman, *"General Intelligence," Objectively Determined and Measured*, 15 AM. J. PSYCHOL. 201 (1904).

46. *See* Gur & Gur, *supra* note 4, at 297.

47. *Id.*

48. *See id*. at 296.

49. *See generally* Arthur L. Benton, *Differential Behavioral Effects in Frontal Lobe Disease*, 6 NEUROPSYCHOLOGIA 53 (1968).

50. *See* P. Stafiniak et al., *Acute Naming Deficits Following Dominant Temporal Lobectomy: Prediction by Age at 1st Risk for Seizures*, 40 NEUROLOGY 1509, 1511 (1990).

51. *See* Donald T. Stuss, *Functions of the Frontal Lobes: Relation to Executive Functions*, 17 J. INT'L NEUROPSYCHOLOGICAL SOC'Y 759, 763 (2011).

52. *See* ARTHUR L. BENTON ET AL., MULTILINGUAL APHASIA EXAMINATION (3d ed. 1994); Janis M. Peyser et al., *Guidelines for Neuropsychological Research in Multiple Sclerosis*, 47 ARCHIVES NEUROLOGY 94, 96 (1990).

53. *See Clinical Neuropsychology*, AM. BOARD PROF PSYCHOL., http://www.abpp.org/i4a/pages/index.cfm?pageid=3304 (last visited Oct. 16, 2016) [https://perma.cc/V3X3-ZHCS].

collect precise data on verbal fluency and language comprehension and find evidence that such functions were impaired in patients with left hemispheric stroke as inferred from hemiplegia (loss of sensation in one side of the body) or hemiparesis (paralysis of a limb) of the right side of the body.[54] It became possible to document performance on face memory and find that it is associated with temporal lobe damage in the right hemisphere because it was observed in patients with seizure disorders predominantly involving, or starting with, the left side of the body.[55] But one could never determine the precise location of the stroke or the seizure focus. Furthermore, it is difficult to learn how a system works by only knowing about what happens when parts of it break.

Progress has therefore accelerated exponentially with the advent of neuroimaging. In the late 1970s and early 1980s, methods became available for safely and reliably measuring brain function and structure in humans.[56] Electroencephalography (EEG) enabled the measurement of changes in the brain's activity, but localization was hampered by the attenuation and smearing of the brain's electrical signal by the skull bone and tissue.[57] Among the first methods for measuring parameters related to the brain's metabolic activity was the xenon-133 clearance technique, which measured regional cerebral blood flow (CBF).[58] Using this method, it was discovered that, among other things, CBF increases during cognitive activity compared to a resting (default mode) state and that it increases more in the left hemisphere for a verbal-reasoning task and in the right hemisphere for a spatial task.[59] This methodology was augmented by positron emission tomography (PET), which allowed three-dimensional measurement of both CBF and metabolism.[60] Spatial resolution was initially low (about 1.5 cm^3) but it reaches 3–4 mm^3 with modern devices.[61]

The introduction of magnetic resonance imaging (MRI) further enhanced the scope and pace of research linking brain systems to behavior. Advanced MRI methodology can generate multimodal information on the

54. *See* Arthur L. Benton, *Historical Notes on Hemispheric Dominance*, 34 ARCHIVES NEUROLOGY 127, 128–29 (1977).

55. *See* Kerry deS. Hamsher et al., *Facial Recognition in Patients with Focal Brain Lesions*, 36 ARCHIVES NEUROLOGY 837, 838 (1979); *see also* Andrew J. Saykin et al., *Memory Deficits Before and After Temporal Lobectomy: Effect of Laterality and Age of Onset*, 9 BRAIN & COGNITION 191 (1989).

56. *See generally* Ruben C. Gur, *Imaging the Activity of the Human Brain*, 67 NAT'L F. 13, 13–15 (1987).

57. *See* SAEID SANEI & J.A. CHAMBERS, EEG SIGNAL PROCESSING 7 (2007) ("The skull attenuates the signals approximately one hundred times more than the soft tissue.").

58. *See generally* Walter D. Obrist et al., *Regional Cerebral Blood Flow Estimated by 133-Xenon Inhalation*, 6 STROKE 245 (1975).

59. *See* Ruben C. Gur & Martin Reivich, *Cognitive Task Effects on Hemispheric Blood Flow in Humans: Evidence for Individual Differences in Hemispheric Activation*, 9 BRAIN & LANGUAGE 78, 79 (1980).

60. *See generally* M.E. Phelps et al., *Tomographic Measurement of Local Cerebral Glucose Metabolic Rate in Humans with (F-18)2-Fluoro-2-Deoxy-D-Glucose: Validation of Method*, 6 ANNALS NEUROLOGY 371 (1979).

61. *See* G.B. SAHA, BASICS OF PET IMAGING: PHYSICS, CHEMISTRY, AND REGULATIONS 100 (2010).

brain, with exquisite spatial resolution.[62] MRI can segment the cranial volume into compartments (gray matter, white matter, cerebrospinal fluid) and provide reliable information on regional brain volume.[63] More novel MRI sequences can provide measures of white matter structural integrity through diffusion tensor imaging (DTI).[64] Such measures can tell us about how well different regions are structurally interconnected.[65] Resting state CBF can also be measured with magnetic resonance (MR) using arterial spin-labeling methods,[66] and resting state connectivity and response to neurobehavioral probes can be quantified with blood oxygenation level dependent (BOLD) measures.[67] Application of these methodologies has generated more precise models of brain system involvement in regulating behavior. For example, functional MRI (fMRI) studies have shown activation of the frontal system when participants were deliberating ethical dilemmas.[68]

As methodology improved for assessing both behavior and brain structure and function, neuropsychology has matured into one of the most vibrant fields of science. Data have been converging from clinical studies to experimental neuroimaging studies—as well as from animal studies we have not discussed here—that enable firm associations between behavior and brain structure and function. For example, by examining neuroanatomical and neurophysiological substrates of specific neurocognitive domains, such as social cognition, we can bridge between brain processes and behavior.[69] Neuropsychology, or cognitive neuroscience, once a small discipline at the intersection of psychology,

62. *See* Alexandra R. Aarons et al., *Experimental Protocols for Behavioral Imaging: Seeing Animal Models of Drug Abuse in a New Light*, *in* BRAIN IMAGING IN BEHAVIORAL NEUROSCIENCE 93, 98 (Cameron S. Carter & Jeffrey W. Dalley eds., 2012).

63. *See* Mark I. Kohn et al., *Analysis of Brain and Cerebrospinal Fluid Volumes with MR Imaging* (pt. 1), 178 RADIOLOGY 115, 115–16 (1991); *see also* Lyn M. Gaudet & Gary E. Marchant, *Under the Radar: Neuroimaging Evidence in the Criminal Courtroom*, 64 DRAKE L. REV. 577, 584 (2016) ("It is generally recognized that MRI produces a better image than CAT scans because there is a greater contrast between soft tissues, including gray and white matter, which results in a clearer image of brain structures.").

64. *See, e.g.*, Wim Van Hecke et al., *DTI Analysis Methods: Voxel-Based Analysis*, *in* DIFFUSION TENSOR IMAGING: A PRACTICAL HANDBOOK 183, 197 (Wim Van Hecke et al. eds., 2016).

65. *See* Vani Rao et al., *Diffusion Tensor Imaging Atlas-Based Analyses in Major Depression After Mild Traumatic Brain Injury*, 24 J. NEUROPSYCHIATRY CLINICAL NEUROSCIENCE 309, 313–14 (2012).

66. Arterial spin-labeling methods use magnetic labeling of the blood flowing to the brain to quantify cerebral perfusion. *See, e.g.*, John A. Detre et al., *Arterial Spin-Labeled Perfusion MRI in Basic and Clinical Neuroscience*, 22 CURRENT OPINION NEUROLOGY 348 (2009); Thomas T. Liu and Gregory G. Brown, *Measurement of Cerebral Perfusion with Arterial Spin Labeling* (pt. 1), 13 J. INT'L NEUROPSYCHOLOGICAL SOC'Y 517 (2007).

67. *See generally* Bharat B. Biswal, Joel Van Kylen & James S. Hyde, *Simultaneous Assessment of Flow and BOLD Signals in Resting-State Functional Connectivity Maps*, 10 NMR BIOMEDICINE 165 (1997); Ruben C. Gur et al., *An fMRI Study of Sex Differences in Regional Activation to a Verbal and a Spatial Task*, 74 BRAIN & LANGUAGE 157 (2000).

68. *See generally* Karla Schneider et al., *Neural Correlates of Moral Reasoning in Autism Spectrum Disorder*, 8 SOC. COGNITIVE & AFFECTIVE NEUROSCIENCE 702 (2013).

69. *See generally* Ruben C. Gur & Raquel E. Gur, *Social Cognition as an RDoC Domain*, 171 AM. J. MED. GENETICS 132 (2016).

neurology, and psychiatry, has become among the showcases of success in applying scientific methodology to understanding the mind.[70]

C. The Beginnings of the Application of Neuroscience to the Law

The implications of neuropsychological knowledge to law have become more evident as demonstrated by their impact on decisions related to culpability. MRI studies have examined the developmental trajectories of different brain systems and shown, for example, that maturation of frontal lobe regions—which are related to executive function—is incomplete until early in the third decade of life.[71] Such data have relevance to criminal culpability of adolescents and individuals with frontal lobe damage.

Indeed, scholars have marveled at the relatively recent emergence of neuroscience testimony in courts.[72] The proliferation has coincided with the decline of much of forensic science after the 2009 National Academy of the Sciences report castigated critical components of the field such as polygraph testing.[73] Relatively recent U.S. Supreme Court decisions like *Atkins v. Virginia*[74] and *Roper v. Simmons*[75] show the increasing influence new knowledge of brain behavior can have at the highest levels of the law, and emerging technologies have shown the potential of neuroscience to fulfill a truth-seeking function in court.[76]

II. DR. RUBEN GUR'S INITIAL INVOLVEMENT IN MEDICAL-LEGAL CONSULTATION AND TYPICAL ANALYTICAL PROCESSES EMPLOYED BY DR. GUR IN THE LEGAL CONTEXT

Dr. Ruben Gur's foray into medical-legal consultation has afforded him some insights into the application of neuroscience to the law. In describing

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70. *See generally* Ruben C. Gur, *Prospective Community Studies Linking Cognitive Deficits to Subclinical Symptoms and a Step Toward Precision Medicine*, 73 JAMA PSYCHIATRY 109 (2016).

71. *See generally* Junko Matsuzawa et al., *Age-Related Volumetric Changes of Brain Gray and White Matter in Healthy Infants and Children*, 11 CEREBRAL CORTEX 335 (2001); *cf.* Jay N. Giedd & Judith L. Rapoport, *Structural MRI of Pediatric Brain Development: What Have We Learned and Where Are We Going?*, 67 NEURON 728, 729–30 (2010); Ruben C. Gur, *Brain Maturation and Its Relevance to Understanding Criminal Culpability of Juveniles*, 7 CURRENT PSYCHIATRY REP. 292, 292 (2005).

72. *See, e.g.*, Nita A. Farahany, *Neuroscience and Behavioral Genetics in US Criminal Law: An Empirical Analysis*, 2 J.L. & BIOSCIENCES 485, 485–86 (2016).

73. *See* NAT'L RESEARCH COUNCIL, NAT'L ACADS., STRENGTHENING FORENSIC SCIENCE IN THE UNITED STATES: A PATH FORWARD (2009) [hereinafter STRENGTHENING FORENSIC SCIENCE], https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf [https://perma.cc/E8H3-T9VA]; NAT'L RESEARCH COUNCIL, NAT'L ACADS., THE POLYGRAPH AND LIE DETECTION, COMMITTEE TO REVIEW THE SCIENTIFIC EVIDENCE ON THE POLYGRAPH (2003) [hereinafter THE POLYGRAPH AND LIE DETECTION], http://www.ministryoftruth.me.uk/wp-content/uploads/2013/07/nas-polygraph.pdf [https://perma.cc/5TCU-KN9T].

74. 536 U.S. 304 (2002).

75. 543 U.S. 551 (2005).

76. *See* Daniel D. Langleben et al., *Polygraphy and Functional Magnetic Resonance Imaging in Lie Detection: A Controlled Blind Comparison Using the Concealed Information Test*, J. CLINICAL PSYCHIATRY (forthcoming 2016).

the methods utilized by Dr. Gur in the medical-legal field, Part II.A first tracks his involvement in medical legal consultation. Part II.B then describes methodological approaches to medical-legal consultation and analysis.

A. Dr. Gur's Experience in Medical-Legal Consultation

In the late 1970s, Dr. Gur became involved in cutting-edge research aimed at harnessing the evolving neuroimaging technology to understand the neural substrates of behavior.[77] The research required extensive study of healthy people that identified factors that influence measures of brain function and structure and required study of normative sex differences and effects of age. The clinical goal of the research was to understand how various brain disorders affect such measures across the lifespan.[78] In that process, Dr. Gur gained experience working with clinical populations and applying budding neuroimaging methods in diagnosis and treatment planning. In one case, he testified:

> The first PET scanner I worked with was called PET three. It was technically the third PET scanner that was ever built. And when MRI came on the scene[,] because of my background and work in imaging in relation to behavior[,] I was involved with that work literally from the outset.[79]

This research was both basic, involving healthy populations, and clinical, with neurological patients (e.g., suffering from stroke, seizure disorders, tumors, head injuries, movement disorders, and dementias) and psychiatric patients (primarily suffering from psychosis, mood disorders, and conduct disorders). The resulting normative PET database—the largest in the country at the time—became known to Dr. Frank Wood, a neuropsychologist who also was involved in neuroimaging. Dr. Wood was involved in a medical-legal case in which a PET scan was performed on the defendant. Dr. Wood called Dr. Gur and asked if he could compare his results to Dr. Gur's normative PET database.[80] Most regional-to-whole-brain ratios obtained by Dr. Wood on the defendant were well within the normal expected range of the controls. The measured value for the

77. *See, e.g.*, Gur & Reivich, *supra* note 59.

78. *See, e.g.*, Ruben C. Gur et al., *Sex and Handedness Differences in Cerebral Blood Flow During Rest and Cognitive Activity*, 217 SCIENCE 659 (1982); *see also* Raquel E. Gur et al., *Brain Function in Psychiatric Disorders* (pts. 1–3), 40 ARCHIVES GEN. PSYCHIATRY 1250 (1983), 41 ARCHIVES GEN. PSYCHIATRY 695 (1984), 42 ARCHIVES GEN. PSYCHIATRY 329 (1985); Martin Reivich et al., *Positron Emission Tomographic Studies of Sensory Stimuli, Cognitive Processes and Anxiety*, 2 HUM. NEUROBIOLOGY 25 (1983).

79. Transcript of the Testimony of Doctors Helen Mayberg and Ruben Gur at 104–05, United States v. Montgomery, No. 05-6002-CR-SJ-GAF, 2007 WL 2711511 (W.D. Mo. Sept. 13, 2007).

80. *See generally* Ruben C. Gur et al., *Sex Differences in Regional Cerebral Glucose Metabolism During a Resting State*, 267 SCIENCE 528 (1995) [hereinafter Gur et al., *Sex Differences*]; Ruben C. Gur et al., *The Effect of Anxiety on Cortical Cerebral Blood Flow and Metabolism*, 7 J. CEREBRAL BLOOD FLOW & METABOLISM 173 (1987) [hereinafter Gur et al., *The Effect of Anxiety*].

amygdala—a critical region responsible for dealing with threat and the main trigger of fight-or-flight behavior—was, however, several standard deviations below the control group from the normative sample. The next day, Dr. Gur was called to testify in that capital case in Florida state court.[81]

The case was that of Robert "Bobbie" Joe Long (a.k.a. the "classified ad rapist"), a man convicted of serial rape and murder in Florida in the early 1980s who received twenty-eight life sentences in 1986 and was sentenced to death.[82] Prior to his crimes, he had sustained a severe head injury from a motorcycle accident. An opposing expert, Dr. Leon Prockop, chairman of the Department of Neurology at the University of South Florida, testified that "Drs. Raquel and Ruben Gur are leading experts in the country on PET research and interpretation."[83]

For Dr. Ruben Gur, the first time testifying as a neuroscience expert in court was memorable, providing opportunities to clinically observe Long's behavior. During the trial, the defendant was kept in a separate room because he was easily agitated, screaming out of control, and threatening his lawyers and the judge. He could still be heard occasionally screaming from the remote room. Upon examining the defendant during a break in the trial, Dr. Gur noted that Long displayed other signs of frontal lobe damage, including disinhibition and tactlessness.[84] Although subsequently sentenced to death,[85] as a mitigating factor the sentencing judge listed that "Long's ability to conform his conduct to the requirements of law was substantially impaired."[86] After that, Dr. Gur began receiving referrals, mostly from defense lawyers in death penalty cases, but occasionally from prosecutors in criminal cases and attorneys in civil cases when a question of brain damage arose.

A decade later, Dr. Gur was contacted by Marc Bookman from the Homicide Unit of the Defender Association of Philadelphia.[87] Bookman,[88]

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81. *See* Initial Brief of Appellant at 21–22, Long v. Florida, 689 So. 2d 1055 (Fla. 1997) (No. 83,593).

82. *See id.* at 2; *Corrections Offender Network: Inmate Population Information Detail*, FLA. DEP'T CORRECTIONS, http://www.dc.state.fl.us/ActiveInmates/detail.asp?Bookmark=3&From=list&SessionID=666993367 (last visited Oct. 16, 2016) [https://perma.cc/447K-W9YA]; *see also Long*, 689 So. 2d at 1056–57 (detailing the complex procedural history of Long's foray with the Florida criminal justice system after his initial death sentence).

83. Initial Brief of Appellant, *supra* note 81, at 21.

84. For example, while measuring his cranial circumference, Long gyrated his hips while commenting "anything else you want to measure, Doc?"

85. *See* Initial Brief of Appellant, *supra* note 81, at 1. Incidentally, note that Long's death sentences (for several crimes) were appealed multiple times and vacated multiple times on procedural grounds unrelated to his brain trauma. *See generally Long*, 689 So. 2d 1055.

86. Initial Brief of Appellant, *supra* note 81, at 22.

87. Empirical research suggests that, between 1994 and 2005, public defenders in Philadelphia were more effective for their clients than private appointed counsel in homicide cases. *See* JAMES M. ANDERSON & PAUL HEATON, MEASURING THE EFFECT OF DEFENSE COUNSEL ON HOMICIDE CASE OUTCOMES 6 (2012), https://www.ncjrs.gov/pdffiles1/nij/grants/241158.pdf [https://perma.cc/3YFG-YFSZ]. Based on data drawn from a sample of 3,412 "defendants charged with murder . . . in municipal court," *id.* at 6, research showed that

> [c]ompared to private appointed counsel, [Philadelphia] public defenders reduce[d] the murder conviction rate by 19%. They reduce[d] the probability that their

involved in a case where the defendant committed capital crimes as a juvenile, requested an affidavit summarizing the literature on brain development and its implications for legal culpability.[89] As brain development was a major research area for Dr. Gur, he had already summarized much of the literature reviewed in the submitted affidavit in a grant application and for a forthcoming manuscript for a psychiatric journal.[90] The research showed that indices of brain maturation in regions related to impulse control and decision making—the frontal cortex involved in executive functions—did not reach their apex until after age twenty-one, and lawyers felt that this impacted legal culpability.[91] The affidavit eventually became part of an amicus brief to the U.S. Supreme Court in *Roper*, which held that individuals cannot be sentenced to death for crimes committed before turning eighteen.[92]

As the methodology became more widely known and standardized, more referrals in. Colleagues were recruited to perform part of the analysis for which they already had a standardized procedural workflow. For example, Dr. Andrew Newberg, a nuclear medicine physician who performs and analyzes PET scans routinely, processed the PET scans, while Dr. Christos Davatzikos, a nationally renowned image analysis expert, processed the MRI data. With participation of postdoctoral students and support staff at the University of Pennsylvania, Dr. Ruben Gur established a "Neuroforensics Service" at Penn, using the reimbursements to further research into brain processes pertinent to violent behavior. Since 2007, with the assistance of criminologist Dr. Oren Gur, a systematic process has been developed to respond to requests for assessment of behavior, brain structure, and function.

B. Dr. Gur's Procedures for Preparing Neuroimaging Expert Testimony and for Reporting Findings from Neuroimaging and Neurological Studies

There are several procedures to employ when a legal team requests neuroscience-based analyses. Part II.B.1 explains the typical procedure for preparing expert testimony that incorporates neuroimaging. Part II.B.2 then

> clients receive a life sentence by 62%. Public defenders reduce[d] overall expected time served in prison by 24%. This suggests that defense counsel makes an enormous difference in the outcome of cases.

Id. at 3.

88. Marc Bookman now directs the Atlantic Center for Capital Representation (ACCR).

89. *See generally* Ruben C. Gur, Brain Maturation in Juveniles: Some Implications for Behavior and its Control, A Literature Review (Aug. 2005) (unpublished manuscript), http://www.njjn.org/uploads/digital-library/resource_243.pdf [https://perma.cc/CPB7-ZNEP].

90. *See generally* Gur, *supra* note 71.

91. *See generally* Gur, *supra* note 89.

92. *See* Roper v. Simmons, 543 U.S. 551, 568 (2005); *see also* Jeffrey Rosen, *The Brain on the Stand*, N.Y. TIMES MAG. (Mar. 11, 2007), http://www.nytimes.com/2007/03/11/magazine/11Neurolaw.t.html?pagewanted=print&_r=1& [https://perma.cc/TGE4-HZQ9].

describes how findings from neuropsychological and neuroimaging studies are reported.

1. Procedure for Preparing Expert Testimony Involving Neuroimaging

Over the years, a standard procedure has been developed for obtaining and analyzing behavioral (neuropsychological), structural (MRI), and functional (PET) neuroimaging data for both civil and criminal cases where linkage was needed between behavior and brain function. When contacted by a lawyer, the first step is to find out whether there is evidence of brain damage and, if so, whether neuropsychological test results or neuroimaging studies are available that document or indicate brain dysfunction. If the answer is positive (and schedule permitting), Dr. Ruben Gur will discuss the case to determine whether available data are sufficient or more data need to be collected. For example, neuroimaging records should exist electronically, and would typically be stored in the Digital Imaging and Communications in Medicine (DICOM) format. If available, neuroimaging records, such as MRI and PET scans, are requested and reviewed by respective experts to determine whether they are of appropriate quality for a quantitative "comparison analysis."[93] When prior neuroimaging is not available, efforts are made as necessary to guide legal teams in how to locate appropriate facilities, consult with referring physicians on which MRI and PET specifications to request, and, once imaging has been conducted, analyze the data.

While neuroscience techniques are the focus of our efforts, they are usually not the only and are rarely the first materials upon which we rely. Often, other records are available for review (e.g., school, medical, military, or criminal) that may help gauge the probability of brain dysfunction in

93. *See* John H. Blume & Emily C. Paavola, *Life, Death, and Neuroimaging: The Advantages and Disadvantages of the Defense's Use of Neuroimages in Capital Cases—Lessons from the Front*, 62 MERCER L. REV. 909, 913–14 (2011) (noting that with regard to comparison analysis, the "traditional mode of neuroimaging analysis has been a visual review of the scan films by a radiologist or a neurologist" and that such a method "creates a number of problems related to subjectivity, bias, and error"). Quantitative analysis, such as that employed by Dr. Gur, allows for the application of validated computer algorithms to analyze data generated during an imaging study. Methods have been developed for quantitatively analyzing these data to obtain precise measures of brain structure and function. Such data are obtained from healthy individuals, and these provide "normative" information that can help identify "abnormal" brains. Overall, "[q]uantitative analysis results in a more precise—and, it is hoped, more accurate—determination of whether the brain is structurally and functionally normal. Furthermore, quantitative anslysis [sic] can permit a comparison of an individual client's brain to a database of brains with known abnormalities (such as schizophrenia)." Blume & Paavola, *supra*, at 914; *see also* Gaudet & Marchant, *supra* note 63, at 591 ("One way to account for this individual variability in the analysis is to employ quantitative methods that compare an individual defendant's data to large data sets that can help define 'normal' for purposes of allowing an expert to determine whether there are statistically significant findings in a defendant's scan"); *cf.* David. L. Faigman et al., *Group to Individual (G2i) Inference in Scientific Expert Testimony*, 81 U. CHI. L. REV. 417, 422 (2014) (noting the distinction between scientific and diagnostic testimony and associated considerations).

specific cases. In most cases, this work is done in the context of an in-depth evaluation by another clinician, neuropsychologist, or neuropsychiatrist, who integrates our analysis with the history and their own clinical interviews to render a diagnosis. When such an expert is not available or retained, however, and a complete diagnostic workup is requested, Dr. Gur will complement analysis of neuropsychological and neuroimaging modalities by conducting personal clinical evaluations and administering a computerized neurocognitive battery (CNB). The CNB is a compilation of tasks used in functional neuroimaging studies to document which brain regions are involved in performing specific tasks.[94] The CNB tasks have been adapted in large-scale genomic studies for use as biomarkers (endophenotypes) of behavior related to brain systems[95]—their use in genomic studies is part of the effort to understand brain and behavior down to the molecular level. Use of the CNB permits more rigorous neuroscience-based characterization of brain systems involved in a patient's specific deficits than that afforded by standard neuropsychological test batteries.[96]

In cases where a complete diagnostic workup is requested, additional records are reviewed when available, such as social, medical, educational, military, criminal, and other relevant official statistics generated by agencies, including information pertaining to the immediate offense and litigation. Notably, record review can be time intensive and not cost effective when done by neuroimaging experts, and, in our experiences, the record is best perused and summarized by an investigator or mitigation specialist already involved with the case and instructed or trained on what to look for (e.g., head injuries, substance use, alcohol use by mother, inconsistent school performance, or time in public housing with lead paint).[97]

94. *See* Ruben C. Gur et al., *A Cognitive Neuroscience-Based Computerized Battery for Efficient Measurement of Individual Differences: Standardization and Initial Construct Validation*, 187 J. NEUROSCIENCE METHODS 254, 254 (2010) [hereinafter Gur et al., *Cognitive Neuroscience-Based Computerized Battery*]; Ruben. C. Gur et al., *Computerized Neurocognitive Scanning* (pt. 1), 25 NEUROPSYCHOPHARMACOLOGY 766, 766 (2001) [hereinafter Gur et al., *Computerized I*]; David R. Roalf et al., *Neurocognitive Performance Stability in a Multiplex Multigenerational Study of Schizophrenia*, 39 SCHIZOPHRENIA BULL. 1008, 1010 (2013). "The battery has been translated to multiple languages and administered more than 200,000 times in studies around the world." Gur & Gur, *supra* note 4, at 301 n.V.

95. *See generally* Tiffany A. Greenwood et al., *Analysis of 94 Candidate Genes and 12 Endophenotypes for Schizophrenia from the Consortium on the Genetics of Schizophrenia*, 168 AM. J. PSYCHIATRY 930 (2011).

96. *See generally* Ruben C. Gur et al., *Computerized Neurocognitive Scanning* (pt. 2), 25 NEUROPSYCHOPHARMACOLOGY 777 (2001) [hereinafter Gur et al., *Computerized II*].

97. While not all cases are as apparent as Robert Joe Long's motorcycle accident, many individuals referred for assessment have quite troubled pasts. For example, in one case, Drs. Ruben and Oren Gur traveled to California to assess an individual who huffed solvents from an early age, was regularly raped by older youths after being placed in foster care, experienced a range of other traumas, and then went on to kidnap and murder as an adult. As a child, another California client was forced by his alcoholic father to get into fistfights with his peers, while the father would take bets on the outcome. These early head traumas may have played a role in his misidentification of innocent victims as rival gang members based on the color of their shirts and his impulsive response that resulted in their deaths.

2. Reporting of Findings from Neuropsychological and Neuroimaging Studies

Reports can be issued at different phases—as requested by the legal team—and multiple reports are often written for the same case, reflecting the emergent nature of information gleaned from the multifaceted approach to linking brain function and structure to behavior. Usually, the first step is to examine available neuropsychological test results. In many cases, such testing is available from both sides, and opposing neuropsychologists argue about whether they indicate brain dysfunction. Often, these tests include measures of "effort" in which easy tasks are disguised as difficult, and someone who tries malingering a deficit will fail them. If a defendant scores below the level of performance achieved by demented individuals, or at a range of scores generated by research participants asked to fake deficits, the neuropsychologist may claim that the defendant is malingering deficits. In typical cases, opposing neuropsychologists will administer several such tests, and if any of them is "failed" by the defendant, the neuropsychologists will argue on whether this means that the defendant is malingering. When there is no evidence of malingering, opposing neuropsychologists usually argue about whether tests in which the defendant performed poorly coalesce to indicate dysfunction in a brain system relevant to the legal issue at hand.

Penn's Neuroforensics Service evaluates the neuropsychological test data received from other experts carefully because the protocols are complicated and scoring itself often requires expert interpretation. The task of reviewing the scoring is usually done by advanced postdoctoral fellows trained in clinical neuropsychology who are versed with current approaches to test administration and scoring, equipped with the necessary manuals and norms, and supervised by a board-certified neuropsychologist. Because interpretation may vary among neuropsychologists, even when they agree on the scores, an algorithm was developed that in effect "consults" with leading experts who rendered their interpretations quantitatively without any knowledge of the specific case at hand.[98] This algorithm was developed in the late 1980's in collaboration with four prominent neuropsychologists (Professors Arthur Benton, Edith Kaplan, Harvey Levin, and Andrew Saykin).[99] Each expert went over each of the neuropsychological tests available at the time (most of which are still used today) and placed numbers indicating the likelihood that damage in that area would be associated with impaired performance.[100] They repeated the assignment a year later, obtaining high levels of interrater and intrarater reliability—meaning each expert consistently gave the same ratings

98. *See generally* Ruben C. Gur et al., "*Behavioral Imaging"—A Procedure for Analysis and Display of Neuropsychological Test Scores* (pts. 1–3), 1 NEUROPSYCHIATRY NEUROPSYCHOLOGY & BEHAV. NEUROLOGY 53 (1988), 1 NEUROPSYCHIATRY NEUROPSYCHOLOGY & BEHAV. NEUROLOGY 87 (1988), 3 NEUROPSYCHIATRY NEUROPSYCHOLOGY & BEHAV. NEUROLOGY 113 (1990).

99. *See generally id.*

100. *See generally id.*

compared to themselves (i.e., over time), and their ratings were similar to the those of the other experts.[101] Using an algorithm based on these expert ratings, we can enter the defendant's neuropsychological test results and generate an "image" of the brain in which the color scale indicates brain regions that are dysfunctional according to the experts who contributed the "weights." With this algorithm, we can consult experts separately or use their virtual average.

The process and validation of this "behavioral imaging" (BI) algorithm have been published in peer-reviewed journals,[102] and the output of the algorithm helps illustrate areas of dysfunction.[103] While an expert neuropsychologist should be able to draw conclusions about brain dysfunction from the test results alone, the neuropsychologist could be biased about specific tests, miss relative deficits that point to the involvement of other regions, or simply fail to integrate the totality of performance measures. The BI can help identify areas that may have been missed by visual inspection of the values or complement interpretation with knowledge from renowned and highly experienced clinical neuropsychologists. An objective algorithm is especially helpful in an adversarial medical-legal situation. People may be biased; the algorithm is not, and it can help in interpreting the results of complex assessments and analyses.

An initial report, based on records and a BI, may suggest that neuroimaging seems appropriate given what the behavioral data indicate about the pattern and extent of deficits. The report can suggest what additional information is needed and how it can be obtained. If the BI suggests brain damage, then structural neuroimaging (MRI) and functional neuroimaging (PET) can be recommended.[104] Because most clients in capital cases are unable to travel to Penn for scanning, this stage may involve communication with a scanning facility adjacent to the prison or as directed by the court.[105] Once the results of MRI and PET become available, a second report would follow, which might also include results of the CNB and clinical assessment. The dates and locations of all

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101. *See generally id.*

102. *See, e.g.*, *id.*; *see also* Lee Xenakis Blonder et al., *Neuropsychological Functioning in Hemiparkinsonism*, 9 BRAIN & COGNITION 244 (1989).

103. For example, a *Wired* article included a picture and description of a behavioral image. *See* Greg Miller, *Did Brain Scans Just Save a Convicted Murderer from the Death Penalty?*, WIRED (Dec. 12, 2013, 6:30 AM), http://www.wired.com/2013/12/murder-law-brain/ [https://perma.cc/HHJ9-V9PH].

104. It is noteworthy that our methodology is quite sensitive to the presence of brain damage, in some cases finding abnormalities even though the clinical reading by neuroradiologists reports no abnormalities. Although such findings can be criticized as "false positives," there is evidence that clinical readings miss effects of diffuse injuries such as those caused by mild traumatic brain injury. *See, e.g.*, Erin D. Bigler, *Neuroimaging Biomarkers in Mild Traumatic Brain Injury (mTBI)*, 23 NEUROPSYCHOLOGY REV. 169, 183 (2013).

105. Initially, Dr. Gur had to travel to the site to ensure that the correct sequences were executed and the data were properly stored, but today most scanning facilities administer the essential sequences for valid quantitation and can store results in DICOM format.

assessments and names of other experts involved are included in the reports.

Volumetric structural analysis of MRI are presented based on quantitative analysis and examination through delineation of regions of interest (ROI) assisted by a semiautomated, template-warping algorithm applied by the developer of the algorithm, Christos Davatzikos.[106] Regions showing a reduction in volume of at least 1.5 standard deviations (SDs) below normal, and their corresponding contralateral structures, are displayed. Results may show, for example, that the overall volume of the defendant's brain is in the normal range, except for reduced volume in the frontal lobe (responsible for "executive functions" such as planning, decision making, and regulation of impulses) and the limbic system (responsible for regulation of emotions) on the left (the cerebral hemisphere responsible for verbal mediation of perception and action). Examining more specific regions within the lobes may show that volumes of the frontal pole and posterior frontal orbital regions are reduced as well as those of the hippocampus or amygdala. These important nodes of the brain system regulate emotional behavior, and reduced volume in these regions could impair one's ability to modulate threat-related behavior or consider morals or the law in situations of stress.

Results of PET establish the regional distribution of cerebral glucose metabolism using fluorine-18 labeled deoxyglucose (FDG).[107] The PET provides measures of the rate at which different brain regions consume sugar (glucose). Because neuronal activity requires energy, which is derived from metabolizing sugar, the metabolic rate is an index of activity in these regions. PET FDG studies are typically done at what is known as a "resting state"—where the participant is not actively engaged in any task—to provide a measure of the brain's default mode state.[108] Dr. Andrew Newberg offers a clinical reading of the scan in a report, which includes images of the PET scans. The PET study is subjected to a quantitative analysis using a standard ROI approach.[109] The quantitative analysis of cerebral metabolic rates relative to the whole brain can support Dr. Newberg's clinical reading and may point to more specific sets of regions that show abnormal glucose uptake. For example, the analysis may indicate relative decreases in regions such as the amygdala and hippocampus and abnormally high metabolism in cortical areas, which could further complicate behavioral regulation of emotions. It has been established that regions that are hypoactive (have reduced metabolism) in the default mode state become activated during a task or challenge, whereas regions that are

106. *See generally* Dinggang Shen & Christos Davatzikos, *HAMMER: Hierarchical Attribute Matching Mechanism for Elastic Registration*, 21 IEEE TRANSACTIONS ON MED. IMAGING 1421 (2002).

107. *See, e.g.*, SAHA, *supra* note 61.

108. *See generally* Debra A. Gusnard & Marcus E. Raichle, *Searching for a Baseline: Functional Imaging and the Resting Human Brain*, 2 NATURE REVIEWS NEUROSCIENCE 685 (2001).

109. *See generally* Gur et al, *Sex Differences*, *supra* note 80; Gur et al., *The Effect of Anxiety*, *supra* note 80.

hyperactive during the default mode state become deactivated during a challenge.[110] An individual with low-resting metabolism in the amygdala and high-resting metabolism in cortical regions will be vulnerable to loss of control when challenged because the amygdala, which issues the fight-or-flight signal, will be activated while the cortex, or "thinking brain," becomes hypoactivated. The situation is analogous to a car that begins accelerating while the defective breaks are already engaged.

CNB testing is used to further establish behavioral manifestations of regional brain dysfunction. The computerized battery was validated through functional neuroimaging[111] and proved sensitive to the existence of major neuropsychiatric disorders, such as schizophrenia.[112] It is scored by automated procedures and yields measures of accuracy and speed on several major neuropsychological domains. These include (1) executive: abstraction and mental flexibility (ABF), attention (ATT), and working memory (WME); (2) episodic memory: verbal (VME), spatial (SME), and facial memory (FME); (3) complex reasoning: language (LAN); (4) social cognition: spatial processing (SPA) and emotion processing (EMO); and (5) sensorimotor speed of information processing (SM).[113]

Results may show that the defendant performed both accurately and with normal speed on several domains but that his performance severely lapsed in the verbal memory and spatial processing tasks and was moderately impaired in abstraction, mental flexibility, and emotion identification. The relevance of such impairments to the case are explained—reports will conclude with a summary of the results of neuropsychological and computerized neurocognitive testing, as well as structural and functional imaging, highlighting convergent areas of brain impairment and their meaning. Ascertaining the etiology of abnormalities can be difficult, requiring clinical evaluation and integration with historical information that was not recorded with the present circumstances in mind. Opinions on neuroimaging findings must meet standards of scientific validity.

III. PRACTICAL LESSONS LEARNED

This part presents some of the practical lessons learned over the years from the perspective of a neuroscientific expert asked to offer opinions in the legal realm. They include (A) testify only to what you know, (B) try to remain current with the field, (C) each case is unique, (D) it is important to utilize mitigation specialists, (E) courts and experts may vary in their knowledge and understanding of neuroscience methodology, and (F) jurors

110. *See, e.g.*, Gusnard & Raichle, *supra* note 108, at 688–89.

111. *See generally* Gur et al., *Cognitive Neuroscience-Based Computerized Battery*, *supra* note 94; Gur et al., *Computerized I*, *supra* note 94; Ruben C. Gur et al., *Neurobehavioral Probes for Physiologic Neuroimaging Studies*, 49 ARCHIVES GEN. PSYCHIATRY 409 (1992); Roalf et al., *supra* note 94.

112. *See, e.g.*, Gur et al., *Computerized II*, *supra* note 96; Greenwood et al., *supra* note 95.

113. *See generally* Gur et al., *Cognitive Neuroscience-Based Computerized Battery*, *supra* note 94.

across the country are interested in neuroscience. These are intended to help court actors appropriately incorporate neuroscientific evidence and testimony into future litigation.

A. Testify Only to What You Know

Expert witnesses sometimes make statements that are either inaccurate or outright ignorant, which is easy to do in complex areas. Experts must be careful to opine only in areas where they feel knowledgeable and stay away from overreaching or overstating the evidence. Experts also should be mindful of the limitations of the technology and be ready to explain these limitations. Finally, as experts review the reports of opposing experts, they often are tasked with responding to information they are not qualified to comment on; acknowledging as much preserves the integrity of the spirit of having experts offer their opinions to the courts and public.

B. Try to Remain Current with the Field

Quite a few experts are well versed in medical-legal proceedings but are not keeping up with the scientific discipline that should inform their testimony. What experts learned about their field during their training many years ago is most likely outdated. This is especially true in a rapidly evolving field such as neuroscience, where foundational knowledge is undergoing transformation and dogmas are being constantly challenged. The number of scientific papers is increasing exponentially, and it is difficult to keep up with the accumulating knowledge. Laboratories performing high-quality research have proliferated, refining the scientific understanding of the brain and behavior. Concurrently, there are more law schools teaching lawyers-to-be about the relationship between neuroscience and the law, and there are centers specializing in the overlap. These groups would benefit from continuing to incorporate neuroscientific advances into curricula. There also are more advanced tools available for finding and summarizing scientific information, and experts have a duty to avail themselves of these tools. Lawyers may do well to seek experts who are at the forefront of their field and can offer an informed perspective.

C. Each Case Is Unique

An independent analysis can be offered by approaching each consultation with an open mind about the defendant (if not yet convicted) or offender (if participating in postconviction litigation) and utilizing procedures that control for the potential influence of any biases stemming from the nature of the crime or legal situation. For example, neuroimaging findings may help inform why the crime was committed in a particular way (e.g., without planning, without the ability to consider long-term consequences, or without emotion or remorse). Appreciating the uniqueness of each case pertains not only to the background of the offender, details of the instant charges, and the nature of the information provided but also to the type of opinion requested, the knowledge that various court actors have of neuroscience, the stage of the criminal justice process at which one gets involved, the types of instruments and assessments employed, and the range of interactions that may occur in adversarial legal arenas.

In some cases, information regarding the offender's medical and criminal backgrounds are not reviewed, and an opinion might be offered based predominantly on the quantitative analysis of neuropsychological and neuroimaging data. In such cases, opinions may not be offered linking such findings to specific behaviors, nor should the expert offer, let alone dispute, a specific diagnosis reached by personal clinical examinations. It is possible, however, to opine about the types of behavioral problems that may manifest themselves in individuals with similar cognitive deficits or regional brain abnormalities if such deficits or abnormalities exist.

D. It Is Important to Utilize Mitigation Specialists

It has been suggested that neuroscience evidence is an influential mitigating factor for some jurors, leading them to sentence offenders to life in prison rather than the death penalty.[114] However, the potential usefulness of such technologically based analyses, particularly in capital cases, often relies in large part on preparation by relatively "old-fashioned" investigative efforts of mitigation specialists. Mitigation specialists can collect information on the defendant's medical history, including incidents of head injuries and other insults to the brain, as well as familial, social, and educational history. They can help locate available results of existing psychological testing conducted throughout the defendant's life course and any prior imaging studies or neuropsychiatric evaluations. Just as the role of neuroscience in the courts has continued to evolve, so has the subspecialty of capital mitigation.[115]

E. Courts and Experts May Vary in their Knowledge and Understanding of Neuroscience Methodology

Some courts and court actors are more familiar with neuroscience than others. Capital cases often are inherently complex; the successful incorporation of neuroscience evidence requires that at least one member of the legal team become immersed in the neuroscience aspects of the case. In some cases, for example, we learned months later (i.e., after any appeal could be filed) that attorneys and judges had failed to recognize seemingly

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114. *See* Deborah W. Denno, *The Myth of the Double-Edged Sword: An Empirical Study of Neuroscience Evidence in Criminal Cases*, 56 B.C. L. REV. 493, 494–99 (2015). Conversely, it has also been suggested that the influence of neuroscience has been overstated, particularly in capital cases. *See* Gaudet & Marchant, *supra* note 63, at 590 ("The second point is that a 2011 study that surveyed the impact of neuroimaging evidence on over 1,400 potential jurors found no such prejudicial effects of neuroimages presented in the context of a mock criminal case. This large-scale empirical study undermines these concerns and suggests that jurors would not be unduly influenced by neuroimages.").

115. *See, e.g.*, JOSÉ B. ASHFORD & MELISSA KUPFERBERG, DEATH PENALTY MITIGATION: A HANDBOOK FOR MITIGATION SPECIALISTS, INVESTIGATORS, SOCIAL SCIENTISTS, AND LAWYERS (2013).

rudimentary issues such as the distinction between *functional* MRI (fMRI) and the more routinely used *structural* MRI (sMRI). Indeed, during an fMRI, the person whose brain is being scanned is *actively engaged* in watching or listening to stimuli projected onto a screen in the scanner and is responding to what they are seeing or hearing by pressing buttons on a fiber-optic response device. In contrast, before a routine sMRI, the person whose brain is scanned is instructed before the scan begins to remain still for the duration of the scan. Moreover, they are not given a task, and whatever they are doing during the scan, short of moving their head, is not going to influence the results of structural analysis of their brain anatomy.

The distinction is important, as (1) our team has never assessed a client with fMRI in the medical-legal context; (2) there have been few successful attempts to admit assessments of defendants utilizing fMRI in capital cases; and (3) there have been cases where a law review article about *fMRI*[116]—rather than scientific, peer-reviewed articles—was inappropriately used to inform the court about the relevance of an analysis that only involved *sMRI*.[117] These types of errors can have a domino effect in the context of a particular case or for future cases in which the expert, or other experts, testify about the brain and behavior. For example, the inappropriate dismissal of or failure to introduce neuroscience evidence pretrial can have long-term adverse effects on subsequent litigation (e.g., appeals). Failure to appeal a decision to bar testimony based, in part, on the consideration of inappropriate and irrelevant material also can negatively impact litigation.[118]

F. Jurors Across the Country Are Interested in Neuroscience

Across the country, jurors appear to be interested in learning how the brain regulates behavior. They are willing to endure and can handle complicated testimony, especially when there is an effort to facilitate their understanding through visualizations and appropriate examples from familiar situations. Almost every juror knows someone with mental health problems or brain dysfunction. Some may know, for example, a relative with Parkinson's disease who became a compulsive gambler or recall

116. *See generally* Teneille Brown & Emily Murphy, *Through a Scanner Darkly: Functional Neuroimaging as Evidence of a Criminal Defendant's Past Mental States*, 62 STAN. L. REV. 1119 (2010). The article specifically notes that it does not refer to sMRI: "It is important to reiterate that in narrowing our focus to *functional* brain images addressed to past mental states, *we are not evaluating structural brain images* such as those that result from X-ray, CT, or regular MRI scans." *Id.* at 1125 n.18 (emphasis added).

117. *See* Transcript of Record at 91, Massachusetts v. Chism, No. 2014-0109 (Mass. Super. Ct. Dec. 3, 2015) ("Finally, the Court notes the Stanford Law Review article, 62 Stanford Law Review 1119, where Through a Scanner Darkly: Functional Neuroimaging as Evidence of Criminal Defendant's Past Mental Studies (sic) raises serious concerns about this type of evidence where the prejudice cannot be mitigated through cross-examination." (alteration in original)).

118. *See generally id.* (exemplifying how a judge relied on a law review article about *fMRI* to make a decision pertaining to an *sMRI* analysis performed by Dr. Ruben Gur).

someone who started behaving impulsively following a head injury. They often are relieved to learn that such behaviors are not manifestations of corrupt character but direct results of damage to the frontal lobe associated with both Parkinsonism and traumatic brain injury. Juror interest is further indicated by the types of clarifying questions they have asked and feedback to members of legal teams about what testimony was impactful and helpful in reaching a decision.

While not exhaustive, keeping these issues in mind may be helpful in building bridges from the legal to the scientific arena. Hopefully, the thoughtful application of neuroscience in the court will improve the quality of justice.

IV. OBJECTIONS TO NEUROSCIENCE EVIDENCE

A common response to neuroscience applications in capital cases, among the public and in some academic and legal circles, is that such testimony offers an excuse for violence by deflecting responsibility from the person to a brain structure. This argument has been articulated by Stephen Morse, a professor of law and psychiatry at the University of Pennsylvania, who noted: "Brains don't kill people. People kill people."[119] As is hopefully evident from the preceding text, the brain controls behavior, and behavior informs culpability. Therefore, Morse's characterization is somewhat of a caricature of the nature of neuroscience's involvement in the court. First, in most cases, neuroscience evidence is presented during sentencing as a mitigating factor.[120] Here, neuroscience is presented as one of myriad possible mitigating circumstances postconviction, which may also include testimonials from school friends, teachers, and family. If someone's kindergarten teacher can offer relevant testimony, how could a neuroscience expert documenting brain dysfunction not be germane?[121]

Second, as argued elsewhere,[122] from the standpoint of neuroscience, Morse's statement is either tautological or dualistic and hence flawed. Because behavior is considered by neuroscientists to be the product of brain processing, and killing is a behavior, the statement "Brains don't kill people. People kill people" makes as much sense as its contrapositive: "People don't kill people. Brains kill people."[123] Neuroscience offers a level of explanation for behavior, which is inherent to the question of culpability and mitigation.

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119. Virginia Hughes, *Head Case*, 464 NATURE 340, 342 (2010).

120. *See generally* Jessica M. Salerno & Bette L. Bottoms, *Emotional Evidence and Jurors' Judgments: The Promise of Neuroscience for Informing Psychology and Law*, 27 BEHAV. SCI. & L. 273 (2009).

121. *See* Denno, *supra* note 114, at 495 ("Courtroom battles over mitigating and aggravating evidence are a common aspect of capital cases, but the unprecedented use of neuroscience evidence in these battles has led to some striking outcomes."); Gaudet & Marchant, *supra* note 63, at 623 ("A defendant charged with a capital offense has the right to present virtually any evidence in mitigation during the penalty phase, and courts are constitutionally required to consider any relevant mitigating evidence.").

122. *See* Gur & Gur, *supra* note 4, at 308–09.

123. *Id.* at 308.

Another objection raised by both academics and in court, usually by the prosecution, can be phrased as follows: "If this brain damage that you showed is responsible for this horrific crime, aren't there many other people with this type of damage who aren't going around killing people?" This question, compelling as it seems, fails to consider the complexity of the brain as it interacts with complicated situational factors. In capital cases, a catastrophic crime *has* occurred, and neuroscience data may prove to a reasonable degree of professional certainty that brain damage impaired the defendant's capacity to make his behavior conform to the law. This impairment in the defendant, however, does not mean that an average individual with the same brain damage is likely to commit the same crime. Rather, in considering the totality of the defendant's circumstances, someone with such brain damage is more vulnerable to failures in controlling behavior.

An analogy from a system that is considerably simpler than the brain can help explain the distinction. Cars, built by humans and hence with clearly designed structure and function (i.e., each and every component is known and its function and design understood), are much simpler than brains. Like the human brain, an issue with one component of a car can have severe ramifications for the rest of the car. For example, in 2014, it was estimated that about thirty million cars potentially had faulty ignition switches,[124] which could "move easily out of the 'Run' position into 'Accessory' or 'Off,'" disabling "the affected car's frontal airbags."[125] Fortunately, the number of fatalities caused by this faulty feature has seemingly been low, as a combination of events are required for it to end in a deadly accident (e.g., engine stalling during an accident or high speeds). This has nothing to do with the fact that each and every one of these fatalities was caused by the faulty switch. Problems with the switch could affect the entire car and other cars as well.

Very similar analogies can be drawn to Toyota's "Potential Accelerator Pedal Entrapment,"[126] which caused unexpected acceleration, and the faulty Takata airbag that contained "shrapnel-shooting inflator parts."[127] Again these are two components that are vital to the functioning of the car but only in intense situations will the malfunction show. Absent such intense

124. *See GM Agrees $900m Settlement for Faulty Ignition Switches*, BBC (Sept. 17, 2015), http://www.bbc.com/news/business-34276419 [https://perma.cc/Y67R-WW7X].

125. Press Release, U.S. Att'y's Office S.D.N.Y., Manhattan U.S. Attorney Announces Criminal Charges Against General Motors and Deferred Prosecution Agreement with $900 Million Forfeiture (Sept. 17, 2015), https://www.justice.gov/usao-sdny/pr/manhattan-us-attorney-announces-criminal-charges-against-general-motors-and-deferred [https://perma.cc/QRP2-9WYN].

126. Press Release, Toyota, Toyota Announces Details of Remedy to Address Potential Accelerator Pedal Entrapment in the U.S. (Nov. 25, 2009), http://www2.toyota.co.jp/en/news/09/11/1125.html [https://perma.cc/2Z2H-LZPH].

127. Clifford Atiyeh & Rusty Blackwell, *Massive Takata Airbag Recall: Everything You Need to Know, Including Full List of Affected Vehicles*, CAR & DRIVER, http://blog.caranddriver.com/massive-takata-airbag-recall-everything-you-need-to-know-including-full-list-of-affected-vehicles/ (last updated Sept. 28, 2016) [https://perma.cc/Q4QU-H94C].

circumstances, these cars fulfill their normal roles without a hitch. Overall, someone with brain damage would be more vulnerable to lapses in conforming their behavior to socially accepted norms or considering the legal ramifications of their actions, particularly in stressful situations. Dysfunction in certain regions of a brain, when overstimulated and unable to handle the neural activation associated with particular situations, can supersede the normal functionality of brain regions that control behavioral responses to provocative situations.

CONCLUSION

Notwithstanding the objections, paradoxical or otherwise, it is likely that neuroscience will continue to play a role in jurisprudence and that its inclusion will only increase. The field is becoming more accessible to other experts and the public. Indeed, its ability to shed light on increasingly subtle aspects of human behavior is evolving rapidly.

The technologies described herein can contribute not only to improved sensitivity for detection of brain abnormalities but also can inform the truth-seeking function of the justice system. For example, fMRI methods for lie detection have been described and validated.[128] While the polygraph is not currently accepted in court,[129] there is reason to believe that fMRI vastly outperforms polygraphy.[130] Unlike polygraphy, lie detection with fMRI does not rely on the subject's autonomic response to lies, which may be attenuated in someone who is not anxious about lying. Instead, it turns on the extra step required by the brain to divert a more veridical response. This methodology is likely to encounter even greater resistance, but eventually it could become useful to the extent that it is reliable and valid.

Although explaining neuroscience methods can become increasingly challenging—as it frequently involves the explication of complex analytical techniques—the increased prevalence of tools that illustrate a data set's relevant features likely will aid in mitigating such challenges. And contrary to assertions that such illustrations are designed to mislead or confuse the jury,[131] they are typically the products of standardized rigorous data processing techniques published in scientific, peer-reviewed journals. Indeed, because the illustrations are necessarily complicated and sometimes

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128. *See, e.g.*, C. Davatzikos et al., *Classifying Spatial Patterns of Brain Activity with Machine Learning Methods: Application to Lie Detection*, 28 NEUROIMAGE 663 (2005); D.D. Langleben et al., *Brain Activity During Simulated Deception: An Event-Related Functional Magnetic Resonance Study*, 15 NEUROIMAGE 727 (2002); Daniel D. Langleben et al., *Telling Truth from Lie in Individual Subjects with Fast Event-Related fMRI*, 26 HUM. BRAIN MAPPING 262 (2005).

129. *See, e.g.*, United States v. Scheffer, 523 U.S. 303, 305, 309 (1998) (upholding Military Rule of Evidence 707, which bars polygraph evidence in military trials); *cf.* STRENGTHENING FORENSIC SCIENCE, *supra* note 73; THE POLYGRAPH AND LIE DETECTION, *supra* note 73.

130. *See generally* Langleben et al., *supra* note 76.

131. *Cf.* Brown & Murphy, *supra* note 116; Michael J. Saks et al., *The Impact of Neuroimages in the Sentencing Phase of Capital Trials*, 11 J. EMPIRICAL LEGAL STUD. 105 (2014).

tedious, their link to specific brain systems needs to be elucidated by a knowledgeable expert. Those interested in the intersection of neuroscience and the law can look forward to interesting times and debates ahead.