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Neuroscience Basics for Lawyers

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Neuroscience Basics for Lawyers

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Neuroscience is, without a doubt, one of the "hot" disciplines in contemporary science. The advances in neuroscience have come from a cycle of technological and conceptual developments that have led to new models not only of how we think but also of how thought translates into behavior. Neuroscience has spawned a number of interdisciplinary offspring–among them "neurolaw," the application of the insights of neuroscience to problems of law and vice versa.[1] The Mercer University, Walter F. George School of Law Symposium from which this volume of the *Mercer Law Review* has emerged is but one manifestation of a rapidly increasing interest in neurolaw.

As a prelude to diving into the discussions–and sometimes debates–that a neurolaw approach provokes in legal scholarship, a reader should have at least an introductory understanding of the brain and of the tools and models that make up the cognitive revolution. This Article is intended to provide just such an introduction. Those who wish to follow up with additional study have a flood of resources at their disposal. These range from popular works[2] to short scholarly treatments[3] and on to more challenging, graduate-level compendiums.[4]

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1. *See* Oliver R. Goodenough & Micaela Tucker, *Law and Cognitive Neuroscience*, 6 ANN. REV. L. & SOC. SCI. 61 (2010).

2. *See, e.g.*, SANDRA AAMODT & SAM WANG, WELCOME TO YOUR BRAIN: WHY YOU LOSE YOUR CAR KEYS BUT NEVER FORGET HOW TO DRIVE AND OTHER PUZZLES OF EVERYDAY LIFE (2009); RITA CARTER ET AL., THE HUMAN BRAIN BOOK (1st American ed. 2009).

3. *See, e.g.*, Oliver R. Goodenough & Kristin Prehn, *A Neuroscientific Approach to Normative Judgment in Law and Justice*, 359 PHIL. TRANS. R. SOC. LOND. B. 1709 (2004);

Undergraduate texts can serve as very useful entry-level guides,[5] and there are many online resources as well.[6] Most of the information set out in this Article can and should be sourced authoritatively to these and similar works rather than to this introductory Article.[7]

I. TECHNICAL DEVELOPMENTS

Neurolaw has been made possible as a field of study by the technological advances that have fueled cognitive neuroscience more generally. Until relatively recently, science was largely unable to study the actual workings of the brain while the brain engaged in thought and guided behavior. Getting inside the skull of a living person was a near impossibility. For some years, psychology focused on behavior–the outward manifestation of a mental process.[8] To the extent that the underlying processes were considered, the discussion was based on a certain amount of self-reporting and internal reflection. The impenetrability of the mental "black box" was not fully complete, however. Lesion cases, such as those involving injuries from strokes, war wounds, or industrial accidents like the famous Phineas Gage case, provided some

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Owen D. Jones et al., *Brain Imaging for Legal Thinkers: A Guide for the Perplexed*, 2009 STAN. TECH. L. REV 5.; Paul J. Zak, *Neuroeconomics*, 359 PHIL. TRANS. R. SOC. LOND. B. 1737 (2004).

4. *See, e.g.*, MICHAEL S. GAZZANIGA, THE COGNITIVE NEUROSCIENCES (4th ed. 2009); HUMAN BRAIN FUNCTION (Richard S. J. Frackowiak et al. eds., 2d ed. 2004).

5. *See, e.g.*, BERNARD J. BAARS & NICOLE M. GAGE, COGNITION, BRAIN, AND CONSCIOUSNESS: INTRODUCTION TO COGNITIVE NEUROSCIENCE (2d ed. 2010); MICHAEL S. GAZZANIGA ET AL., COGNITIVE NEUROSCIENCE: THE BIOLOGY OF THE MIND (3d ed. 2009).

6. The website of the Law and Neuroscience Project at www.lawneuro.org and its bibliographic resource at www.lawneuro.org/Resources/Bibliography.aspx are good starting points for an explanation of neurolaw. At the scholarly level, the Interdisciplinary Research Centre for Neurosciences of the Johannes Gutenberg-University of Mainz has compiled an extensive online bibliography of neuroethics, http://www.linguistik.unimainz.de/schlesewsky/publications, that includes many sources relating to neuroscience and law. A bibliography aimed at law and the biological sciences more generally is available at http://law.vanderbilt.edu/seal/resources.htm.

7. A reasonable compendium of neurolaw scholarship can be found in Goodenough & Tucker, *supra* note 1. At the risk of leaving good work unmentioned, the following compendium volumes provide concentrated doses of work at the intersection of law, morality, and neuroscience: LAW AND THE BRAIN (Semir Zeki & Oliver R. Goodenough eds., 2006); LAW, MIND AND BRAIN (Michael Freeman & Oliver R. Goodenough eds., 2009); 2 MORAL PSYCHOLOGY: THE COGNITIVE SCIENCE OF MORALITY (Walter Sinnott-Armstrong ed., 2008); NEUROSCIENCE AND THE LAW: BRAIN, MIND, AND THE SCALES OF JUSTICE (Brent Garland ed., 2004); THE IMPACT OF BEHAVIORAL SCIENCES ON CRIMINAL LAW (Nita A. Farahany ed., 2009).

8. *See* B.F. SKINNER, SCIENCE AND HUMAN BEHAVIOR (1953); JOHN B. WATSON, BEHAVIORISM (Norton 1924).

information about anatomical function.[9] The limits, however, on what could be known about living brain processes in humans made behaviorism a reasonable and often fruitful approach.

Over the past two decades, this picture has changed radically. Science has discovered progressively more sensitive and powerful techniques for investigating the electrical, neurochemical, and metabolic correlates of brain function linked to particular kinds of thoughts, tasks, and behaviors. The black box of the brain became amenable to study after all, and the results have been spectacular.

Early technologies for capturing data on the processes of thought included various kinds of external electrical measurements. Some external electrical measurements–such as galvanic skin conductance–measure systemic electrical properties across wide swaths of the body. Other measurements–like electroencephalography (EEG) and magnetoencephalography (MEG)–provide information on patterns of electrical activity within the brain. These measures are quite precise as to the *timing* of activity; they are much less successful at providing localization information.

II. NEUROIMAGING

The most widely recognized breakthroughs have involved scanning techniques known collectively as neuroimaging. These technologies look for an attribute or by-product of some brain function–often linked to heightened metabolism in an active area–which can be detected by a targeted external mechanism, even when located deep in the brain. Directional measurements–often referred to as "slices"–are made and then subjected to complex mathematical processing called tomography, resulting in a reliable mapping of the distribution of the selected attribute onto the brain. When these measurements are captured and paired with the mental activity and behavior stimulated by specific experimental tasks and stimuli, neuroimaging can create increasingly useful models of the workings of thought.

Early on, positron emission tomography (PET) scans played an important role. In this technique, a short-lived radioactive isotope is bound into a targeted molecule. A dose of this combination is injected

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9. *See, e.g.*, ANTONIO R, DAMASIO, DESCARTES' ERROR: EMOTION, REASON, AND THE HUMAN BRAIN (1994); LAWRENCE WEISKRANTZ, BLINDSIGHT: A CASE STUDY AND IMPLICATIONS (1986); John M. Harlow, *Passage of an Iron Bar Through the Head*, 39 B. MED. SURGICAL J. 389 (1848); Roger W. Sperry, *Hemisphere Deconnection and Unity in Conscious Awareness*, 23 AM. PSYCHOL. 723 (1968); *Reading about Phineas Gage*, DEAKIN UNIVERSITY (last updated Jan. 28, 2010), http://www.deakin.edu.au/hmnbs/psychology/gagepage/PgRead.php.

into the bloodstream of the subject, and its decay provides a measurable tracer for the differential distribution of the target molecule in the body. In traditional PET approaches to brain scanning, oxygen and glucose–both are associated with metabolism in the brain–were often used as the basis for the tracer. By establishing the location of heightened metabolism during a particular mental task, we can infer that the location is doing some of the work involved in the targeted cognition. A lowered metabolism can suggest that activity in the area is in some way inhibited in the performance of the task.

PET has limitations of spatial resolution and temporal sensitivity, and its use of injected radioactivity restricts the number of times an individual can be an experimental subject. In recent years, much of the functional scanning activity has shifted over to the fMRI technique, which utilizes a different proxy for metabolism. PET has had some resurgence, however, as science has developed tagging agents that interact with specific types of neuroreceptors associated with one or more of the messenger neurochemicals that are a key element in brain processes.[10] This research is expanding our knowledge of brain function beyond metabolism, providing information on the intersection of location and chemistry with great importance for untangling problems such as addiction.[11]

The fMRI scan[12] is probably the most widely used tool in contemporary cognitive neuroscience.[13] Here, the scan induces a magnetic field in the components of the body and then records how it decays. Differential patterns in this decay help to pinpoint anatomical differences in the targeted tissue, which can include joints and organs as well as the brain. Scans of the brain can be either "anatomical"–showing physical structures–or "functional"–showing areas of increased or lowered blood flow that can be associated with functional activity. The spatial resolution of MRI is continuously improving, and the detail available in a careful anatomical scan is quite remarkable. Functional

10. Alex K. Converse et al., *PET Measurement of rCBF in the Presence of a Neurochemical Tracer*, 132 J. NEUROSCI. METHODS 199, 199-207 (2004).

11. *See* Wynne K. Schiffer et al., *Imaging Addiction with PET: Is Insight in Sight?*, 10 DRUG DISCOVERY TODAY 547 (2005).

12. "MRI" stands for "magnetic resonance imaging." The "f" in fMRI indicates a functional approach.

13. *See, e.g.*, Neal Feigenson, *Brain Imaging and Courtroom Evidence: On the Admissibility and Persuasiveness of fMRI*, *in* LAW, MIND AND BRAIN, *supra* note 7; John C. Gore, *Principles and Practice of Functional MRI of the Human Brain*, 112 J. CLINICAL INVESTIGATION 4 (2003); Jones et al., *supra* note 3.

scans focus in on the "BOLD" response,[14] tracking the increase in the presence of oxygenated blood that follows shortly after increased activity in a particularly active area of the brain. This is, once again, an indicator linked to metabolism, which can be used as an indication of activity with reasonable reliability. Because function is measured over short scanning periods, spatial resolution remains a challenge.

The data produced in an fMRI scan, or any form of tomography for that matter, comes out not as a picture like a photograph but rather as a very large set of readings of relatively small variations in signal strength that must be assembled through a time and computer resource-consuming process. This analysis eventually builds a three-dimensional map of metabolic variation across the scanned regions. These results can then be represented in a pictorial form, often made to look like a kind of direct representation of a human brain. Most often, some illustration of the zone of BOLD signal increase–or decrease–will be plotted onto a model of the brain and is frequently depicted as a spot of bright color. This convention has led to the fundamentally inaccurate but still widely used expression that the activity has made a part of the brain "light up" in the scanner. However vivid the representation of the spot on the brain in the scientist's report, nothing has actually illuminated in the brain.[15] It would be more accurate to say instead that the brain apparently has been more (or less) activated or has done more (or less) work in this region during the activity.

III. DATA ANALYSIS

The end result in the normal imaging study is not a picture of the entire brain at work. To begin with, studies typically focus on a single area of interest. The medical function of MRIs, from which the research has grown, usually targets a "problem area," seeking information that may lead to a diagnosis or treatment. By looking at a limited area of interest, the researcher can limit the size of the data-set subject to the exceptionally complex processing necessary for good tomography and analysis.

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> The commonest method of fMRI is blood oxygenation level-dependent (BOLD) imaging, which has dominated this field since its discovery. BOLD fMRI employs heamoglobin as a convenient endogenous contrast agent, relying on the magnetization difference between oxy- and deoxyhaemoglobin to create the fMRI signal.

Owen J. Arthurs & Simon Boniface, *How Well do We Understand the Neural Origins of the fMRI BOLD Signal?* 25 TRENDS IN NEUROSCI. 1 (2002) (citations omitted).

15. Jones et al., *supra* note 3, ¶¶ 34-35.

Most forms of functional imaging rely on "subtraction analysis." The idea of finding areas of *increased* metabolism necessitates a comparison to some activity state for those areas for which there is a *lower level* of metabolism. In many experimental designs, the targeted mental task is paired with a closely related one that differs only in a carefully controlled element. By subtracting the readings for the baseline task from those of the targeted task, differences in function are highlighted. Because the effects can be quite small and idiosyncratic in any particular individual, the readings are often cumulated across a number of trials and a number of individuals, often involving a pool of twelve or more subjects to achieve statistically significant effects. Thus, the pretty pictures of activation regions frequently relate to an average among many subjects rather than to the pattern of anyone in particular.[16] In fact, even in a good study, it is possible that none of the subjects has a pattern of activity that corresponds completely to all of the locations reported as statistically implicated for the task in question.

A further caution to be applied is that subtraction only highlights the anatomy *not shared* by the target and comparison tasks. *Shared* structures and networks, which may be very important for understanding what is happening, will drop out in the comparison. Identifying these overlaps will require different comparison tasks and different subtractions; this is a relatively laborious process, but it is a process that is keeping neuroscientists employed productively around the world, and it is producing better and better models of our cognitive processes. While subject to important limitations and cautions, cumulatively these technological developments constitute a tremendous leap forward. New research is exploring a technique called resting-state analysis that can circumvent some of the limits of the subtraction method and that provides improved insights on the network properties of brain activity. This approach looks not at isolated mental tasks, but rather at the networks of brain regions that interact with each other, determined in this case by tracking interactions that occur naturally in the "resting" brain. This method of analysis will open new doors for research of interest to law and neuroscience.[17]

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16. *Id.* at app., cmt. A25.

17. *See, e.g.*, M.P. van den Heuvel & H.E. Hulshoff Pol, *Exploring the Brain Network: A Review on Resting-State fMRI Functional Connectivity*, 20 EUR NEUROPSYCHOPHARMACOL. 519-34 (2010), *available at* http://www.ncbi.nlm.nih.gov/pubmet/20471808; M.D. Greicius et al., *Functional Connectivity in the Resting Brain: A Network Analysis of the Default Mode Hypothesis*, 100 PROC. NAT'L ACAD. SCI 253-58 (2003).

IV. BRAIN BASICS I: MICROSTRUCTURE

So what are we looking at with all of this new technology? At the level of microstructure, the most important cellular building-block in the brain is the neuron. This specialized cell comes in many configurations. At its most typical, the shape of a neuron is analogous to a tree (indeed, the growth in its outer portions is called "arborization"). The neuron consists of a central body–a soma–with a number of shoots–dendrites–reaching out in a branching pattern to connect with other neurons. While specialized in its function, the soma nonetheless contains many of the same organelles as other cells. On opposite sides of the soma–sometimes referred to as "above" and "below" the soma, evoking the tree metaphor–are the branching dendrites and the trunk-like axon. The dendrites are tendril-like receptors while the long, usually singular, axons are the outward-facing conductors of communication through the release of neurotransmitters.

Neurons send and receive electrical impulses along the network of connections in an idiosyncratic way. Most neurons use electricity to operate *internally* but use chemistry to communicate with *each other*. Neurons are generally not in direct contact. Rather, between the communicating axon of one neuron and the receiving membrane of another is a very small space called a synapse, a distance of between twenty and forty nanometers. Communication between neurons across the synaptic gap–or cleft–occurs through an electrochemical process that is accomplished by releasing neurotransmitters–little molecular messengers–on one side and collecting the neurotransmitters on the other side. To describe the process simply, the axon is responsible for releasing any one of several neurotransmitting chemicals, which are bound to special molecules, into the synaptic gap. The transmitting molecules then diffuse and may bind with receptor proteins on the receiving–or postsynaptic–neuron.

When neurotransmitters hit the receptors of the postsynaptic neuron in sufficient quantity, they cause excitement in the target cell, which can be reinforced by messages from other sending neurons in the target's network. When the target cell achieves a sufficiently excited state, it "fires," releasing neurotransmitters in its own turn and sending a message of excitement to further neurons attached in its network. If, however, the transmission does not raise the receiving cell's electric potential beyond a certain threshold, the transmission fails. This function is an "all or nothing" phenomenon. Once the released neurotransmitters have delivered their message, the frugal processes of the brain work to absorb many of the neurotransmitters back up into their reservoirs for use in the next interchange–a process called reuptake.

Neurotransmitters come in a number of varieties, including such familiar names as dopamine, adrenaline, and serotonin. Research is showing that various structures in the brain have concentrations of neurons with greater or lesser involvement with the different neurotransmitters. The background levels of these chemicals can modulate the strength necessary to send a convincing message across the synapse. Prozac, for instance, is one of a class of drugs called serotonin reuptake inhibitors. By blocking reuptake, the supply of that transmitter in the synapse remains elevated, and the strength of any signal sent using serotonin is reinforced. Opiates, cocaine, and other addictive drugs often have a significant impact on the dopamine system. This impact includes stimulating the learning circuits in the brain, literally teaching the user through his natural processes of instruction that the drug is something positive to be sought out as a major life priority.[18]

Neuroscientists would like to be able to measure the activity of particular neurons as the brain works, and this is sometimes possible. Neuron measurement requires using very precise instruments that are generally applied to or implanted in an exposed brain. While animal studies can permit the implants that allow such precise measurements over a prolonged period, in humans this kind of research is typically limited to patients during surgery. Scanning is not yet able to isolate individual cells; even the most precise scanning methods measure clusters of many thousands of neurons.

V. BRAIN BASICS II: MACROSTRUCTURE

At a somewhat higher level of structure, neurons are connected in networks, both locally and across the brain. The functions of the brain are allocated differentially to overlapping groups of these networks. Some areas, such as those involved in primary visual processing, are quite specific in what they do; others, such as those involved in internal attention monitoring, are recruited as components in a number of different mental tasks. Obtaining a more complete understanding of the structural functionality within the brain is a central goal for cognitive neuroscience. While this study is still very much a work in progress, the picture becomes clearer every day.

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18. Steven E. Hyman, *The Neurobiology of Addiction: Implications for Voluntary Control of Behavior*, 7 AM. J. BIOETH. 8, 10 (2007); Steven E. Hyman, et al., *Neural Mechanisms of Addiction: The Role of Reward-Related Learning and Memory*, 29 ANN. REV. NEUROSCI. 565, 568, 572 (2006).

At the level of macrostructure, the brain is generally divided into a few large features. The naming of these features is a confusing mix of old medical Latin along with more modern names for particular regions and areas. Brodmann's system of identification, introduced in 1909, suggested approximately fifty-two regions of the brain.[19] There are also systems of numbered coordinates. Mastering all of these variations is not necessary for making a start in neurolaw but a working familiarity with several of the most important features probably is.

Perhaps the most prominent feature in brain anatomy is its outer layer, the cortex. The name comes from a Latin root meaning "bark," and as bark does, the cortex forms a highly wrinkled surface that wraps around other principal brain structures. Like many brain features, the cortex has a left and right hemispherical division. Each of these hemispheres has four large regions or "lobes"–the frontal, temporal, parietal, and occipital–working roughly from front to back in the head.

While many processes are distributed across several regions, some gross level associations can be made between these lobes and particular functions. For instance, much of the processing of visual information is performed in the occipital lobe. The parietal lobe is significantly involved in receiving and processing information about touch, pain, temperature, and limb position. Much of our hearing and auditory processing occurs in the temporal lobe. The frontal lobe plays many roles, including directing movements in the sub-area called the motor cortex and planning and executing behaviors of many kinds in the sub-area called the prefrontal cortex. Indeed, this prefrontal area is implicated in many law-salient functions, including social monitoring, inhibition, and self-control. The prefrontal cortex comes up frequently in discussions of law and neuroscience.

Underneath the cortical layer is a further set of structures–the limbic system. The limbic system's components include the thalamus, amygdala, hypothalamus, and hippocampus. This system is implicated in a number of important functions, ranging from quick "fight or flight" style processing of sensory input by the hypothalamus, short and long-term memory formation by the hippocampus, and emotional reaction and regulation in the amygdala.[20] The limbic system can be viewed *partly* as a separate system, but the limbic system also interacts with the cortex in important ways.

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19. Korbinian Brodmann, *Vergleichende Lokalisationslehre der Grosshirnrinde in ihren Prinzipien dargestellt auf Grund des Zellenbaues*, *in* SOME PAPERS ON THE CEREBRAL CORTEX 201, 201-30 (Gerhardt von Bonin ed., Charles C. Thomas 1960) (1909).

20. Abigail A. Baird, *The Developmental Neuroscience of Criminal Behavior*, *in* THE IMPACT OF BEHAVIORAL SCIENCES ON CRIMINAL LAW, *supra* note 7, at 81, 85-87.

Focusing on the separate aspects of limbic system function, some scientists have spoken of a two-track system in the brain, what LeDoux calls the "high road" and "low road."[21] Economists Kahneman and Frederick also argue for a "dual-process model," although it is less concretely tied to the cortex and limbic anatomical divide. The essence of a dual-process model is that judgments can be produced in two ways (and in various mixtures of the two): a rapid, associative, automatic, and effortless intuitive process (System 1), and a slower, rule-governed, deliberate and effortful process (System 2). System 2 "knows" some of the rules that intuitive reasoning is prone to violate and sometimes intervenes to correct or replace erroneous intuitive judgments. Thus, errors of intuition occur when two conditions are satisfied: System 1 generates the error and System 2 fails to correct.[22] While this kind of separation corresponds to our folk psychological understandings–particularly in Western, rationalist societies–the relationship between the cortex system and limbic system is probably more complex and interactive than this somewhat simple model would suggest.

The final anatomical division of the brain is the brainstem. This area at the bottom and rear of the brain provides links from the brain to the rest of the body via the spinal cord. The brainstem is responsible for a number of important regulatory functions, including arousal, alertness, breathing, blood pressure, and heartbeat. The brainstem's relevance to law and neuroscience is most obvious in questions of end-of-life[23] and brain death, as in the famous case of Terri Schiavo.[24]

VI. MODELING COGNITIVE PROCESSES

Cognitive neuroscience takes the physiological understanding as its starting point, and by tracing the electrical, metabolic, and neurochemical correlates in the physiology linked to particular mental tasks and behavioral outcomes, cognitive neuroscience has produced new models of human thought and action. Cognitive neuroscience has also given us

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21. JOSEPH LEDOUX, THE EMOTIONAL BRAIN: THE MYSTERIOUS UNDERPINNINGS OF EMOTIONAL LIFE 161-63 (1996).

22. Daniel Kahneman & Shane Frederick, *Representativeness Revisited: Attribute Substitution in Intuitive Judgment*, *in* HEURISTICS AND BIASES: THE PSYCHOLOGY OF INTUITIVE JUDGMENT 49 (2002).

23. *See, e.g.*, Robin Mackenzie, *Reframing the Good Death: Enhancing Choice in Dying, Neuroscience, End-of-Life Research and the Potential of Psychedelics in Palliative Care*, *in* LAW, MIND AND BRAIN, *supra* note 7, at 239.

24. *See, e.g.*, Timothy E. Quill, *Terri Schiavo–A Tragedy Compounded*, 352 NEW. ENG. J. MED. 1630 (2005).

a coveted first glimpse into the building blocks of personality, abnormality, and mental illness.

At least in part, the new model has undone the Cartesian view of a unified intelligence. Descartes postulated a unitary center of thought that was largely separated from the brain itself and that communicated with the brain via the pituitary gland.[25] A similar conception is widespread in folk psychology and is sometimes expressed in the idea of the homunculus captain–a little human in the center of all our thought and will, ordering the mind and body about like the captain of a ship. The captain may not always be heard by the unruly crew at her command, but our folk psychology presumes that she is there nonetheless. Freud and others in his time made important suggestions about the more fragmented nature of thought, motivation, and action, but Freud also proposed a hierarchical system in the id, ego, and superego (the "captain" again?), and he lacked a solid physiological basis for his necessarily speculative modeling.[26] Indeed, the somewhat primitive exculpatory argument that "my brain made me do it"–rightly condemned by Morse[27]–depends on a kind of fusion of Cartesian and Freudian thinking applied to a cartoon notion of neuroscience: the well-intentioned homunculus captain once again overruled, this time by a "crew" that is manifest in the recalcitrant mechanisms of the brain. Good neuroscience should have no time for such an argument: the processes that create what we inadequately describe as captain and crew are *all* products of brain function, and a theory of decision making, action, and responsibility grounded in neuroscience must take them all into account.

Behaviorism held sway over much of psychology in the mid-twentieth century. At its best, behaviorist psychology recognized that the available models of cognition were inadequate in part because there was such a limited ability in the science of the time to investigate brain function in living humans. The brain was important, but it was a "black box," an organ whose workings were necessarily secret. Thus, behaviorism focused on what a study of action could tell us about the nature of the thought that produced it, often with significant results. At its worst, however, behavioral psychology came to believe that opening up the black box would be irrelevant–or even a threat–to good research.[28] This fundamentalist approach, together with a certain bumptious

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25. *See* DAMASIO, *supra* note 9, at 118-19.

26. *See* SIGMUND FREUD, THE EGO AND THE ID (Ernest Jones ed., Joan Riviere trans., 4th ed. 1947).

27. *See* Stephen J. Morse, *Brain Overclaim Syndrome and Criminal Responsibility: A Diagnostic Note,* 3 OHIO ST. J. CRIM. L. 397 (2006).

28. *See id.* at 402.

assertiveness on the part of those pushing the new cognitive–or thought-based–approaches, sometimes created barriers to the productive integration of behavioral and cognitive work. Luckily, these barriers appear to be eroding rapidly as the neuroscientific approaches bear undeniable fruit.

The new models of thought now emerging have moved decisively away from a unitary, undifferentiated model of thought and have also departed from physical and mental dualism along the Cartesian lines.[29] Rather, thought is seen as the outcome of a distributed, organic process within the brain. Thought is a "computational" process that is physically carried out through the interaction of neurons. This process is highly complex, but it is nonetheless susceptible to scientific study and modeling. Investigating the active biology of mental work will give insights into the processes of thought and behavior. Taking this functionalist approach, when looking at mental activity, we may first ask, "What problem is the brain solving?" The key step in cognitive neuroscience is the expectation that the approach taken by the the individual's mind in solving the problem will be *physically* present in the workings of her brain. By investigating this physical presence, we can in turn gain insights into the types of solutions available to humans and the cues that switch us into a particular approach. These insights will sometimes confirm the folk psychology embodied in our laws, though they will also often expose details and subtleties missed in our less sophisticated formulations. At other times, these insights will challenge our traditional beliefs about mental processes and may stimulate fundamental changes in how law is framed and applied.

VII. THE EXAMPLE OF EMOTION

Emerging work on the cluster of mental processes that we group under the label of "emotion" is a good example of how the new models of thought can bring new insights to old problems. Emotion is a word that in its traditional usage gathers a number of mental processes and experiences together under a single label, and neuroscience helps us to make some useful differentiations. To begin with, we can separate the sensation of arousal that we monitor in ourselves and others–the sensation we label "emotion"–from the functional mental processes that give rise to the sensation.[30]

Neuroscience suggests that at a functional level, the processes we label as emotion act as a kind of emphasizer and highlighter in the brain, an

29. DAMASIO, *supra* note 9, at 250-51.
30. Goodenough & Prehn, *supra* note 3, at 1717.

indicator of importance and urgency.[31] Emotional states direct our attention; our cognition gravitates towards phenomena that have emotional valance.[32] In the realm of memory, events that are accompanied by emotional states are more likely to be transferred from working memory to long-term recollection.[33] This transfer, however, is no guarantee of accuracy; work by Phelps and Sharot has demonstrated that the feeling of certitude that comes with memories formed in an emotional context–like our memories of the events of September 11, 2001–is not justified by greater accuracy in such memories.[34]

Recognizing the functionality of emotion allows us to understand its place in law. Richard Posner, a rationalist who sees some role for emotion in moral and legal judgment, described the traditional suspicion of emotion in legal studies: "The law itself is conventionally regarded as a bastion of 'reason' conceived of as the antithesis of emotion, as operating to rein in the emotionality of the behavior that gives rise to legal disputes."[35]

We now understand, however, that without emotional content, much of the motivational force of normative judgment would be missing.[36] Cass Sunstein has noted the importance of indignation and "moral outrage" as a motivator in the decisions of juries and of legislative decisions.[37] Emotions may also act as guarantors of moral commitments, both in ourselves and in our judgments of others.[38] Emotions are often a necessary part of competent thought, particularly thought that will lead to action. On the other hand, rationalists have a point:

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31. *See, e.g.*, Baird, *supra* note 20; J. Morris & R. Dolan, *Functional Neuroanatomy of Human Emotion*, *in* HUMAN BRAIN FUNCTION, *supra* note 4, at 365, 365-88; R.J. Dolan, *Emotion, Cognition, and Behavior*, 298 SCIENCE 1191 (2002).

32. Adam K. Anderson & Elizabeth A. Phelps, *Lesions of the Human Amygdala Impair Enhanced Perception of Emotionally Salient Events*, 411 NATURE 305, 307-08 (2001).

33. *See* Morris & Dolan, *supra* note 31, at 365-88.

34. Elizabeth A. Phelps & Tali Sharot, *How (and Why) Emotion Enhances the Subjective Sense of Recollection*, 17 CURRENT DIRECTIONS IN PSYCHOL. SCI. 147, 147 (2008).

35. Richard A. Posner, *Emotion Versus Emotionalism in Law*, *in* THE PASSIONS OF LAW 309 (Susan A. Bandes ed., 1999).

36. *See* FREUD, *supra* note 26; LAW, MIND AND BRAIN, *supra* note 7; Posner, *supra* note 34; Oliver R. Goodenough, *Institutions, Emotions, and Law: A Goldilocks Problem for Mechanism Design*, 33 VT. L. REV. 395, 395-404 (2009); Goodenough & Prehn, *supra* note 3.

37. Cass R. Sunstein, *Some Effects of Moral Indignation on Law*, 33 VT. L. REV. 405, 428 (2009).

38. *See* ROBERT H. FRANK, PASSIONS WITHIN REASON: THE STRATEGIC ROLE OF THE EMOTIONS (1988); Robert H. Frank, *Cooperation Through Emotional Commitment*, *in* EVOLUTION AND THE CAPACITY FOR COMMITMENT (Randolph M. Neese ed., 2001); Robert H. Frank, *The Status of Moral Emotions in Consequentialist Moral Reasoning*, *in* MORAL MARKETS: THE CRITICAL ROLE OF VALUES IN THE ECONOMY 42 (2008).

emotion-driven reactions can drive us to responses that are not productive in the long run, a classic "Goldilocks problem" for the law.[39] Scholarship by Terry Maroney is helping to further delineate the role of emotion in particular legal problems and processes.[40]

VIII. CONCLUSIONS

As the example of emotion shows, the new models of thought arising out of cognitive neuroscience can help us to resolve questions in law that have proved hard for traditional psychology and the other social sciences to resolve. The enriched psychology that cognitive approaches make possible is a particularly useful tool in seeking to understand topics when current approaches of law, folk psychology, and traditional academic psychology are not delivering satisfactory results for society. This summary can only begin the process of introducing practitioners and legal scholars to the richness of the knowledge emerging from neuroscience, but even an entry-level understanding can provide intellectual access to the advances–and perhaps steps sideways and even backwards–provided by neurolaw.

39. Goodenough, *supra* note 36, at 402.

40. *See, e.g.*, Terry A. Maroney, *Emotional Common Sense as Constitutional Law*, 62 VAND. L. REV. 851 (2009); Terry A. Maroney, *Law and Emotion: A Proposed Taxonomy of an Emerging Field*, 30 LAW & HUM. BEHAV. 119 (2006).