Neuroscience and the Personalization of Criminal Law

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While objective standards of reasonableness permeate most legal disciplines, criminal law has trended toward personalization since the 1960s, when the Model Penal Code introduced conceptions of mental states based on Freudian psychoanalytic theory. Today, advancements in neuroscience offer previously inconceivable insights into living brain structures and damage. This Essay contends that a criminal justice system that uses personalizing neuroscientific evidence will yield better outcomes. This Essay contributes two unique tools to the personalized law debate. First are the results of my two-decade-long Neuroscience Study, in which I have compiled eight hundred criminal cases that addressed neuroscientific evidence in any capacity. The data gathered from these cases suggest that simplistic views that regard neuroscience as either entirely exculpatory or solely indicative of future dangerousness are misinformed. Second, this Essay posits a probabilistic theory of analyzing evidence based on Bayes's Theorem. Bayes's Theorem offers a compelling model of human reasoning that comports with the process of assessing a defendant's culpability in legal settings. Neuroscientific evidence can thus be understood as a means of modifying initial beliefs and mitigating implicit biases in criminal contexts. Employing these tools, I analyze the impact of personalized evidence on criminal defenses, which I argue are strongly motivated by probabilistic determinations of a defendant's culpability. These determinations have significant impacts beyond individual cases and can contribute to trends in litigation funding. This Essay systematically argues that personalization, fueled by neuroscientific evidence,

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can provide gains in fairness and efficiency, especially when admitted in the context of criminal defenses, due to their emphasis on probabilistic determinations of culpability.

INTRODUCTION

Every criminal case is part of a larger personal story—some headline-grabbing, some entirely mundane; yet each narrative is important to how the criminal justice system assesses an individual's level of culpability. *People v Jones*[1] is one such story: Willie Jones, a seemingly prototypical defendant, exhibited a level of brain trauma that was anything but ordinary.

In 1991, after Jones paid Martha Drumgoole $15 to have sex with him in his home, Drumgoole's lover, Brenda Hardaway, attempted to enter by breaking a window.[2] Believing that Hardaway was either trying to hurt him or burgle his house, Jones shot her seven times, killing her.[3] While the intoxicated Hardaway had a reputation for violence, she seemingly did little at the time to suggest she would either burgle or kill anyone.[4]

Despite this seeming lack of basis, Jones presented a claim of self-defense, contending that he reasonably believed Hardaway was dangerous because he suffered from a gross cognitive impairment that impeded his ability to form intent, process information, and respond appropriately.[5] Because of his brain damage, Jones argued he believed his life was in danger even though a person without brain damage may not have perceived the situation similarly.[6] Indeed, early neurological testing indicated that Jones's mental impairment was so deleterious that his medical experts wanted additional tests to validate and explore his condition—specifically, tests with modern brain imaging devices that could reveal the nature and extent of Jones's injury.[7] In addition, Jones wanted these experts to explain to the jury the extent to which his mental disabilities impacted his behavior.[8]

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1 210 AD2d 904 (NY App 1994).

2 Brief for Respondent, *People v Jones*, No 1578, *1–2 (NY App filed Oct 20, 1994) (Respondent's Brief).

3 Brief for Appellant, *People v Jones*, No 1578, *20 (NY App filed Oct 20, 1994) (Appellant's Brief).

4 See Respondent's Brief at *2 (cited in note 2).

5 Appellant's Brief at *12 (cited in note 3).

6 Respondent's Brief at *12 (cited in note 2).

7 Id at *3; Appellant's Brief at *2 (cited in note 3).

8 Respondent's Brief at *7 (cited in note 2).

The trial court denied Jones's requests, ruling that the defense failed to show the medical reasons for such testing and that the doctors could not testify about the link between Jones's condition and his behavior.[9] A jury convicted Jones of second-degree murder, and he was sentenced to fifteen years to life in prison.[10] Yet the defense appealed the trial court's decision, and the appellate court reversed, concluding that the trial court had abused its discretion by excluding evidence.[11] According to the appellate court, the testing and accompanying expert testimony were "crucial" for Jones's defense because understanding the impact of Jones's brain damage on his behavior and ability to form intent was "outside the ken" of the average juror.[12] The test results and doctors' explanations could help establish that Jones could not have achieved the level of intent necessary to justify a murder charge and that manslaughter more accurately reflected his mental state.[13] Rather than risk losing the case on retrial, Jones and prosecutors agreed to a plea bargain that lowered the murder charge to first-degree manslaughter, which carried a sentence of six to eighteen years in prison.[14]

The courts and defense experts in *Jones* were harbingers of more cases involving neuroscientific evidence and brain trauma. The last thirty years have seen a surge of research in neuroscience, "the branch of life sciences that studies the brain and nervous systems."[15] Innovations such as Magnetic Resonance Imaging (MRI) have enabled researchers to examine living brains—the most personalized and intimate "of all human experiences"—in a way that no previous technology allowed.[16] This neuroscientific research has the potential to revise society's concept of human nature and how the law can handle dangerous criminal behavior. Such a newly constructed perspective is important to criminal law

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9 Appellant's Brief at *6, *14 (cited in note 3).

10 Id at *1.

11 Id; *Jones*, 210 AD2d at 904.

12 *Jones*, 210 AD2d at 904.

13 Id at 904–05.

14 Id.

15 Brent Garland, *Neuroscience and the Law: Brain, Mind, and the Scales of Justice* 206 (Dana 2004). See generally Owen D. Jones and Francis X. Shen, *Law and Neuroscience in the United States*, in Tade Matthias Spranger, ed, *International Neurolaw* 349 (Springer 2012) (providing an overview of neuroscience in many different fields of law).

16 Marc Jonathan Blitz, *Searching Minds by Scanning Brains: Neuroscience Technology and Constitutional Privacy Protection* 2 (Palgrave Macmillan 2017).

because key concepts of culpability depend on assessing the internal workings of individuals' minds.[17]

This Essay presents five major arguments for incorporating a more personalized approach in criminal law.[18] First, a criminal justice system that is more personalized or subjective would likely be more effective, efficient, and fair. Typically the legal system does not reflect people's particular characteristics, traits, and circumstances. In other words, most law is impersonal. Yet in 1962, the American Law Institute's Model Penal Code (MPC) advocated a more subjective approach to criminal law given criminal law's focus on defendants' mental states. The MPC also recognized that the rapid growth in the psychological sciences was revealing increasingly relevant information about how all individuals think and reason. The MPC considered these scientific trends important because they would enable a more refined and accurate conception of a defendant's level of culpability and blameworthiness, therefore establishing fairer and more effective means of punishing, rehabilitating, or deterring such individuals. The importance of psychological science was especially emphasized in the context of criminal law defenses.[19]

This Essay's second argument is that neuroscience is a particularly valuable form of personalized evidence, especially when it is used to evaluate a defendant's level of mental culpability. Until the 1970s, for example, substantial portions of criminal law doctrine reflected a Freudian psychoanalytic conception of a defendant's mental state, not the modern neuroscientific understanding.[20] While both the psychoanalytic and neuroscientific approaches emphasize personalization, I argue that neuroscience better reflects both individual and group criminal behavior.[21]

Third, the greater influx of personalization using neuroscience combats the simplistic and exaggerated perception that the criminal justice system handles defendants in a dichotomous,

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17 See Deborah W. Denno, *Crime and Consciousness: Science and Involuntary Acts*, 87 Minn L Rev 269, 275–76 (2002).

18 For examples of discussions of personalization in other areas of the law, see generally Philip Hacker and Bilyana Petkova, *Reining in the Big Promise of Big Data: Transparency, Inequality, and New Regulatory Frontiers*, 15 Nw J Tech & Intell Prop 1 (2017); Omri Ben-Shahar and Ariel Porat, *Personalizing Negligence Law*, 91 NYU L Rev 627 (2016); Ariel Porat and Lior Jacob Strahilevitz, *Personalizing Default Rules and Disclosure with Big Data*, 112 Mich L Rev 1417 (2014).

19 See notes 32–33 and accompanying text.

20 See Deborah W. Denno, *Criminal Law in a Post-Freudian World*, 2005 U Ill L Rev 601, 657, 660.

21 Id at 682.

all-or-nothing manner when neuroscientific evidence is introduced. Specifically, this influx will counter the notion that the evidence will either be entirely exculpatory or entirely condemnatory for defendants. My research and that of others generally show that neuroscientific evidence offers factfinders additional information about defendants that is more precise, reliable, and granular than what criminal cases have previously provided by way of psychiatric testimony and that courts embrace neuroscientific evidence for this purpose. Indeed, in death penalty cases, the Supreme Court has perceived neuroscientific evidence to be so significant for mitigation that this emphasis has bolstered the defense's ability to win claims of ineffective assistance of counsel if trial attorneys failed to introduce such evidence when it was relevant or if the attorneys mishandled the evidence even if they did introduce it.[22]

Overall, the criminal justice system values personalization despite the overreactive and dichotomous view that some critics point to when weighing neuroscientific evidence. Therefore, my Essay proposes a fourth argument. It advocates a more accurate approach to personalization—one based on a probabilistic framework, which is also "personalistic."[23] With a "personalistic definition of probability different people may have different ideas about the probability of the same event," therefore producing different expected outcomes.[24] Yet such variability should not be of concern to the criminal justice system because it would be anticipated in circumstances "where the evidence is ambiguous and subject to differing interpretations."[25] Not only does a probabilistic approach get us closer to personalization, but it also gets us closer to the truth by helping us better assess neuroscientific data in the pragmatic context of how the legal system operates. Probabilities also help us to withstand dichotomous thinking because they reflect a matter of degree as opposed to an all-or-nothing framework. This Essay's fifth argument focuses on criminal law defenses because they rely most heavily on a highly personalized view of a defendant. A probabilistic framework helps diminish critics' concerns

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[22] See Deborah W. Denno, *The Myth of the Double-Edged Sword: An Empirical Study of Neuroscience Evidence in Criminal Cases*, 56 BC L Rev 493, 505–06 & n 74 (2015).

[23] John Kaplan, *Decision Theory and the Factfinding Process*, 20 Stan L Rev 1065, 1067 (1968).

[24] Id at 1067, 1069.

[25] Id at 1067.

over such personalization because of its emphasis on degrees rather than dichotomies.[26]

A probabilistic approach also fits within the legal and scientific parameters of the criminal justice system. For example, we ask judges, juries, prosecutors, and defense attorneys to make probabilistic determinations all the time. Standards like beyond a reasonable doubt, preponderance of the evidence, and prejudicial versus probative are all configured in a probabilistic framework. In addition, science generally—and neuroscience specifically—are probabilistic tools in that they try to determine the importance or effect of one variable against another or to fulfill a particular statistical standard. Lastly, there is increasing evidence that people themselves inherently think probabilistically. From an early age, our brains search for statistics and combine them with other information in order to make decisions.[27]

This Essay contends that Bayes's Theorem, one type of probability analysis, is particularly fitting for these calculations because it is designed to detect gradations that may otherwise be perceived in terms of dichotomous extremes. In essence, the Theorem is an elementary mathematical formula based on a law of probability that guides us to revise or update our initial beliefs about a proposition based on new and objective information. Such updating provides us with a more accurate, more advanced, and better belief.[28] The Bayes approach can help explain why neuroscientific evidence can be a means of revising and improving a factfinder's initial beliefs about a defendant's level of mental culpability.

The use of Bayes's Theorem raises a number of key questions, however. If there is evidence that people inherently think probabilistically, that key legal standards (such as beyond a reasonable doubt) are probabilistic, and that neuroscience is probabilistic,

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[26] See id at 1070 (explaining that, because "probability and utility are personalistic concepts, the differences [in attempting to quantify them] are mostly of degree rather than kind").

[27] See notes 69, 82, 85 and accompanying text.

[28] See Sharon Bertsch McGrayne, *The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy* ix (Yale 2011). For a fuller description and discussion of the Theorem's more modern usages, see Nate Silver, *The Signal and the Noise: Why So Many Predictions Fail—but Some Don't* 242–61 (Penguin 2012) (noting that Bayes's Theorem is a probabilistic process that reveals the conditional likelihood that a hypothesis is true provided that another event occurs).

why do we even need a Bayesian framework? The answer is because we do not always conduct probabilistic calculations very well; we need some guidance to help us make better decisions. For example, we have implicit biases that make us overvalue some factors—such as race or physical attractiveness—that should be irrelevant in determining a defendant's guilt or a particular punishment. But we also have biases that make us undervalue certain factors—such as neuroimaging evidence—because we do not think it is important (as the trial judge thought in *Jones*) or we think it can bode poorly for the defendant (by heightening the likelihood that a juror may view the defendant as a possible future danger to others and therefore a strong contender for deserving the death penalty).

It is also critical to consider who is making these Bayesian decisions. Depending on the case, it could be any or all of the key legal actors and some at the same time. In the *Jones* trial, the judge was the first decisionmaker, followed by the jury; but after the appeal, the prosecution was the probabilistic decisionmaker in offering a plea bargain, and the defense had to weigh the odds and decide whether to take the deal. In other words, the prosecutor updated his view of the case based on new evidence that he believed could have a substantial impact in a new trial with another jury. He thought a plea bargain would sidestep the risk that he could lose a retrial entirely if the additional testing was introduced.

In essence, a Bayesian framework shows how decisionmakers—whoever they are—start at the baseline and process new data. I argue that the criminal justice system could be more effective, more efficient, and fairer if some of those new data included relevant, personalized information about the defendant. A Bayesian analysis would help that approach along. It would get us closer to the truth and a more accurate assessment of how to treat a criminal defendant.

The purpose of this Essay is to demonstrate the use of a probabilistic and personalized approach in the criminal justice system's consideration of neuroscientific evidence in four types of criminal law defenses: lesser mens rea, insanity, diminished capacity, and incompetence. The analysis draws on an original database that I created consisting of every criminal case that has addressed neuroscientific evidence in any capacity over the course of two decades (totaling eight hundred cases). This analysis thus provides a new statistical and informational method to address

the false dichotomy that such evidence is thought to present, and it uses Bayes's Theorem as part of a normative explanation.

Part I discusses why a personalized approach is important to criminal law. It also describes the "Neuroscience Study," its initial results, and how such research can be used to provide appropriate data for probabilistic assessments. Part II analyzes the reasons for applying a Bayesian approach to examine neuroscientific evidence in the context of defenses and employs the *Jones* case as an example. Part III examines four key criminal defenses under a Bayesian approach and how such a perspective can heighten the value and impact of personalization. Part IV ends with an emphasis on the importance of a personalistic use of probabilistic decision-making in the criminal justice system, especially when evaluating neuroscientific evidence. The discussion also incorporates an evaluation of funding concerns in cases when defendants are requesting the use of certain types of neuroscientific testing and experts, given objections that such sophisticated mitigation tools may not be fully available to all defendants. This focus on available funding further explains how personalization connects to probability and why employing both together makes the criminal justice system more efficient and fairer.

I. WHAT PERSONALIZATION MEANS IN CRIMINAL LAW

Justice Oliver Wendell Holmes espoused the classic perspective that the law disregards personalization and subjectivity—namely "the infinite varieties of temperament, intellect, and education which make the internal character of a given act so different in different men."[29] While Holmes's statement characterizes a number of legal doctrines, including the objective "reasonable person" standard of negligence in tort law,[30] such a generalization about personalization and subjectivity is substantially less clear in criminal law. For example, there is heated disagreement about whether negligent acts should even be eligible for criminal punishment, much less whether the criminal law should have greater or lesser degrees of subjectivity. Indeed, the nature of the objective/subjective balance often varies according to the types of criminal law doctrines or defenses at issue.

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29 Oliver Wendell Holmes Jr, *The Common Law* 108 (Little, Brown, and Company 1881).

30 See Ben-Shahar and Porat, 91 NYU L Rev at 628–29 (cited in note 18).

This objective/subjective debate is also influenced by what philosophy of punishment an individual embraces. Those who advocate a retributive or just deserts model of punishment may be less concerned about evaluating a defendant's personal characteristics or experiences than those who embrace a rehabilitative model, in which individual differences can be highly influential.[31]

The members of the American Law Institute were primarily motivated by a theory of rehabilitation when, in 1962, the organization published its Proposed Official Draft of the MPC—the product of a decade-long effort at revising penal codes throughout the country. The MPC has been hugely influential throughout the country and has been persuasive authority in thousands of court opinions.[32] But it was the MPC's emphasis on incorporating the psychological sciences of the times into its provisions that was such a major component of its power to reform. That science was largely Freudian psychoanalysis and a concomitant emphasis on individual experiences and mental processes. While modern American psychiatry experienced a paradigm shift in the mid-1970s toward biological psychiatry, the curve toward subjectivity and the use of brain sciences remained in criminal law.[33]

Of course, not all states embraced the MPC. And the punitive bent of the 1990s has fueled further tensions between objectivity and subjectivity depending on what theory of punishment one holds. That said, a firm place for subjectivity remains in the criminal law, and the surge of interest in and research on neuroscience has been used to support subjectivity. The following Sections describe my Neuroscience Study and the kinds of highly personalized data it has collected.

A. The Neuroscience Study

The Neuroscience Study—a large-scale empirical research project—offers an unprecedented opportunity to consider how neuroscientific evidence fits into a legal framework from multiple and diverse perspectives, particularly personalization. I collected

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[31] See Joshua Dressler, *Understanding Criminal Law* 129 (Carolina Academic 2018).

[32] See Paul H. Robinson and Markus D. Dubber, *The American Model Penal Code: A Brief Overview*, 10 New Crim L Rev 319, 326–27 (2007) ("Thousands of court opinions have cited the Model Penal Code as persuasive authority for the interpretation of an existing statute or in the exercise of a court's occasional power to formulate a criminal law doctrine."); Denno, 2005 U Ill L Rev at 694–95, 698–744 (cited in note 20) (reviewing all standard jury instructions for mens rea in all fifty states, many of which show the MPC's influence).

[33] See Denno, 2005 U Ill L Rev at 614–15 (cited in note 20).

any criminal law case that addressed neuroscientific evidence in any capacity from January 1, 1992, to December 31, 2012, using the Westlaw and Lexis legal databases. These cases, which totaled 800, produced over 150 key factors relevant to the criminal justice system; they were coded primarily by trained law school graduates who also spot-checked and reviewed one another. The case selection and coding techniques employed for the Neuroscience Study have been described in detail elsewhere, along with the strengths (reliability and validity) and drawbacks (underinclusion) of using only Westlaw and Lexis databases.[34]

1. Overview.

The Neuroscience Study's 800 cases fall into three categories: 247 cases (30.88 percent) concern neuroscientific evidence as it pertains to the victim, primarily to prove the extent of a victim's brain injury; 514 cases (64.25 percent) concern neuroscientific evidence as it pertains to the defendant; and 39 cases (4.88 percent) concern neuroscientific evidence as it pertains to both the defendant and the victim because the brains of one or more individuals in both the "victim" and "defendant" categories were examined.[35] Because this Essay's major focus is criminal defenses, only the latter two categories—"defendant" and "both victim and defendant"—are relevant, totaling 553 cases.

The Neuroscience Study's operational definition of the term "neuroscience" is the investigation of the brain and nervous system based on both imaging tests (such as the MRI) and nonimaging standardized tests (such as the Wechsler test).[36] Overall, the majority of the Neuroscience Study's cases involve defendants convicted of murder or a serious crime, of which a substantial portion (about two-thirds) began as capital cases even if the defendants' sentences were later reduced to noncapital sentences. In addition, noncapital defendants faced long prison sentences of at least a decade or more. Generally, it appears that neuroscientific evidence is used in cases in which defendants face the death penalty, a life sentence, or a decades-long prison sentence—perhaps because the stakes are higher and there is substantially greater time and funding spent on the defense. Lastly, the Neuroscience Study has also revealed that neuroscientific evidence is employed

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34 Denno, 56 BC L Rev at 500–01 (cited in note 22).

35 Id at 501.

36 Id at 504–05.

at different stages of cases, suggesting that in either a capital case or a noncapital case, neuroscience may be incorporated during the guilt determination phase, the penalty phase, or both.[37]

2. Defendants.

In terms of personalizing defendants, the types of testing selected are significant. MRI tests and computerized tomography (CT) scans are the most widely employed types, and most testing is used by defense attorneys to support arguments that defendants suffered from cognitive deficiencies that impacted their mental state.[38] Thus, defendants' arguments pertain to a range of defenses—diminished capacity, insanity, incompetency, or the lack of mens rea necessary to complete the crime.[39] Different testing methods can reveal disorders that are relevant to such defenses, including brain damage, mental deficiency, mental illness, and brain abnormality.[40]

Typically, few claims of ineffective assistance of counsel are successful; yet in the Neuroscience Study, a relatively higher number of cases involve claims that defense attorneys were ineffective because they failed to present neuroscientific evidence.[41] As I have discussed previously, claims of ineffective assistance of counsel are enhanced when they include arguments that attorneys either failed to introduce neuroscientific evidence or did so irresponsibly.[42] Contentions that defendants would be a future danger were far rarer than commentators have assumed, suggesting that neuroscientific evidence is presented more often by the defense for purposes of mitigation than by the prosecution to show that a defendant should be imprisoned for a long time or executed.[43]

B. The Neuroscience Study's Personalized Defenses

The Neuroscience Study shows that neuroscientific evidence is generally raised in cases in which defendants are facing severe sentences. My prior research has also demonstrated that such evidence is most commonly introduced for an important yet relatively conventional purpose: as part of an effort to mitigate a

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37 Id at 502.
38 Denno, 56 BC L Rev at 548 (cited in note 22).
39 See Part III.
40 See Appendix, Figures 2–4.
41 See note 22 and accompanying text.
42 Id.
43 Id.

defendant's sentence.[44] Indeed, the Neuroscience Study has revealed a criminal justice system that is willing to embrace innovative methods of assessing defendants' mental capabilities and expects its attorneys to do the same, as evidenced by courts granting claims of ineffective assistance of counsel.[45] Thus, the greater personalization that such information affords appears to impact how the criminal justice system metes out punishments, especially in the direction of mitigation.

This Essay analyzes how defendants construct personalized defenses, especially those that most readily comport with neuroscientific evidence: lesser mens rea, insanity, incompetency, and diminished capacity. The discussion that follows focuses on the nature and extent to which attorneys attempt to personalize their clients' defenses by relying on probabilistic strategies, particularly those resembling Bayes's Theorem. This probabilistic framework also reflects the broad principles underlying a Bayesian approach to understanding the brain and behavior.[46]

II. THE VALUE OF A BAYESIAN APPROACH

Critics of a more personalized framework in criminal law[47] contend that judges and juries either find neuroscientific evidence confusing or view it simplistically as a double-edged sword[48]—that is, as a vehicle that can absolve a defendant's responsibility for the crime entirely or provide support that the defendant will be a danger to others in the future and therefore deserving of a long prison sentence or even the death penalty. However, a rigorous review of the data tells a different story. My research has shown that such all-or-nothing assumptions ignore both the complexity of the many legal doctrines that rely on neuroscientific evidence as well as the range of brain injuries that can influence perceptions of a defendant's level of culpability.[49] Likewise, there

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44 Denno, 56 BC L Rev at 503 (cited in note 22).

45 Id at 514–25.

46 See generally Konrad Paul Kording, *Bayesian Statistics: Relevant for the Brain?*, 25 Current Op in Neurobiology 130 (2014); Jill X. O'Reilly, Saad Jbabdi, and Timothy E. J. Behrens, *How Can a Bayesian Approach Inform Neuroscience?*, 35 Eur J Neuroscience 1169 (2012).

47 For a thorough discussion of critics on both sides of the debate over neuroscientific evidence and personalization, see generally Peter A. Alces, *The Moral Conflict of Law and Neuroscience* (Chicago 2018).

48 See Denno, 56 BC L Rev at 496–97, 529–31 (cited in note 22).

49 See generally Deborah W. Denno, *Concocting Criminal Intent*, 105 Georgetown L J 323 (2017); Deborah W. Denno, *How Prosecutors and Defense Attorneys Differ in Their Use of Neuroscientific Evidence*, 85 Fordham L Rev 453 (2016); Deborah W. Denno, *The*

is no evidence to demonstrate that case dispositions support such dichotomous outcomes. While neuroscientific evidence can mitigate charges or a prison sentence, as the *Jones* case demonstrated, in other cases its impact may be negligible or too remote to assess. In addition, there is no indication that neuroscientific evidence promotes longer incarceration or a death sentence for an inmate except in particular circumstances.[50]

This Essay contends that a probabilistic approach is a more accurate and realistic reflection of the legal system and also is where the legal system should be going with regard to neuroscientific evidence. Such an approach also helps dispel dichotomous thinking because probabilities involving multiple factors from a Bayesian perspective can reflect changing viewpoints that incorporate a number of different types of personalized information.

A. Construct and Components

Proved initially by the Reverend Thomas Bayes, an eighteenth-century statistician and Presbyterian minister, Bayes's Theorem asks how new information could change an individual's degree of confidence in an initial belief.[51] This practice, also known as Bayesian updating, can be simply described as follows: "[B]y updating our initial belief about something with objective new information, we get a new and improved belief."[52] Over time, labels were designated for each part of the Theorem: the term "prior" represents the probability of the initial belief ($P(A)$); the term "objective new information" (or similar terminology) represents the probability of new information being introduced ($P(B)$); the term "likelihood" represents the probability that there would be other hypotheses in light of the introduction of objective new information ($P(B \mid A)$); and the term "posterior" represents the probability that an individual would construct an updated or revised belief based on this objective new information ($P(A \mid B)$).[53]

This basic theorem is expressed formulaically as follows:

Place for Neuroscience in Criminal Law, in Dennis Patterson and Michael Pardo, eds, *Philosophical Foundations of Law and Neuroscience* 69 (Oxford 2016); Denno, 56 BC L Rev 493 (cited in note 22).

50 See Denno, 56 BC L Rev at 526–27 (cited in note 22).

51 See Richard Price, Preface to Thomas Bayes, *An Essay towards Solving a Problem in the Doctrine of Chances*, 53 Phil Transactions Royal Society London 370, 371–72 (1763).

52 McGrayne, *The Theory That Would Not Die* at ix (cited in note 28). For a fuller description and discussion of its more modern usages, see Silver, *The Signal and the Noise* 242–61 (cited in note 28).

53 McGrayne, *The Theory That Would Not Die* at 8 (cited in note 28).

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

Typical nonlegal applications of Bayes's Theorem often concern estimating the probability of someone getting cancer. For example, a woman in her forties who receives a positive mammogram result may want to know the probability that she has breast cancer. Under a Bayesian approach, she will try to acquire three types of data: (1) the probability that a woman in her forties will get breast cancer (1.4 percent); (2) the probability that the mammogram will detect breast cancer in a forty-something woman who actually has it (75 percent); and (3) the probability that any random forty-something woman without cancer will have a positive mammogram (10 percent). According to Bayes's Theorem, the probability that the woman at issue has cancer in light of her positive mammogram is only about 11 percent, meaning that over nine out of ten positive mammogram results for forty-something women are false positives. The false positives stand out in a situation like this because very few forty-something women actually get breast cancer.[54]

The Theorem and its derivations form the basis of the Bayesian inference technique. The technique is known for its breadth and the persistence of its applications across three centuries in a variety of disciplines so neatly encapsulated in the title of Sharon McGrayne's book, *The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy*.[55] In more recent decades, the Theorem has regained its footing as a means of probabilistic analysis in such areas as cognitive neuroscience, artificial intelligence, and financial modeling.[56]

Despite its range and longevity, however, the Bayesian approach has rarely been applied in the legal context.[57] While there

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[54] Silver, *The Signal and the Noise* at 245 (cited in note 28). The Bayes's Theorem calculation goes as follows: $P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{(0.014) \cdot (0.75)}{0.1} = 0.105 \approx 11\%$.

[55] McGrayne, *The Theory That Would Not Die* (cited in note 28).

[56] See generally id (detailing Bayes's Theorem's application since the time of its discovery up to the present). See also Erica Klarreich, *In Search of Bayesian Inference*, 58 Communications of the ACM 21, 21–22 (2015) (reviewing the many ways Bayes's Theorem has been used); Silver, *The Signal and the Noise* at 242–61 (cited in note 28) (discussing the many dimensions of Bayesian Theory).

[57] Professor John Kaplan's application appears to have been the first, closely followed in time by Michael Finkelstein and Professor William Fairley's article and then

is disagreement on the validity of such an application, this Essay uses the Theorem as a normative gauge and as a means of exploration, essentially a method for weighing different kinds of evidence in a criminal case even if that evidence cannot be measured precisely. Indeed, one of the benefits of the Bayesian approach is its applicability to uncertainty, particularly imprecise or estimated information.[58]

B. Bayesian Updating

Consider how Bayesian updating would apply to the personalized information at issue in *Jones* and the prosecution's decision to plea bargain.[59] Recall that Jones shot and killed Hardaway in reaction to her attempted break-in.[60] The defense argued that Jones was brain damaged and further neurological testing and neuroimaging were needed to show that his reaction in self-defense was reasonable in light of his circumstances and gross cognitive impairment.[61] In addition, the defense argued that experts were necessary to explain to the jury how Jones's disabilities impacted his behavior.[62] The trial court denied the defense's requests, and the jury convicted Jones of second degree murder.[63] Jones successfully appealed.[64] At this point, both the prosecution and defense updated their view of the case based on this potential introduction of new evidence. The prosecution in particular had to recalculate and weigh how significant this new neuroimaging evidence would be to a new jury's decision-making about Jones's culpability. Rather than risk losing at a retrial because this additional testing and expert testimony could be influential, the prosecution agreed to a plea bargain, or a compromise. Jones could plead to manslaughter in the first degree and shave years

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Professor Laurence Tribe's critique of Finkelstein and Fairley. See generally Michael O. Finkelstein and William B. Fairley, *A Bayesian Approach to Identification Evidence*, 83 Harv L Rev 489 (1970); Laurence H. Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process*, 84 Harv L Rev 1329 (1971). Over the years, other articles have sporadically followed these three starting pieces. See generally, for example, Richard Lempert, *The New Evidence Scholarship: Analyzing the Process of Proof*, 66 BU L Rev 439 (1986).

58 See note 67 and accompanying text.

59 See text accompanying note 14.

60 Respondent's Brief at *1–2 (cited in note 2).

61 Id at *12.

62 Id at *7.

63 Appellant's Brief at *1 (cited in note 3).

64 *Jones*, 210 AD2d at 904.

off the sentence he initially received.[65] Presumably, the prosecution was concerned that the additional testing and a new trial could change the initial outcome and result in Jones's conviction for something less than murder, and perhaps even produce an acquittal. Such compromise solutions would be expected in criminal cases that represent what could be considered a Bayesian approach.[66]

As Table 1 of the Appendix shows, Bayes's Theorem as applied to the *Jones* case reflects the prosecutor's response to losing the appeal and his updated decision to plea bargain. A Bayesian approach can incorporate assigned probabilities that can be based on actual data or, as in Table 1, on "invent[ed] numbers" in order to illustrate how such changes or updating can be measured.[67] Table 1 uses such estimates because actual data are presently difficult to access.

Examining Table 1, suppose there are two events at issue in the *Jones* case: Event A, a murder conviction, and Event B, the defense's presentation in court of evidence of brain damage that is probative of culpability. Suppose also that there is some information about Event A that the prosecutor (the consumer of Bayes's Theorem) initially believes has a probability $P(A)$ of being correct (the "prior" probability). In *Jones*, that information could be the probability of a murder conviction among those defendants charged with murder in New York State, which Table 1 estimates is 50 percent. Suppose also that new evidence, B, is factored in, which is the probability $P(B)$ that the defense presents brain damage evidence probative of culpability in any criminal trial in New York State, which Table 1 estimates is 25 percent. Lastly, suppose that there is a 15 percent probability $P(B|A)$ that the defense presented brain damage evidence during trial given (or assuming) that the defendant was convicted of murder. The question we would want to answer is what Bayesian theory calls the "posterior" probability, that is, what is the probability $P(A|B)$ of a murder conviction among those defendants charged with murder given (or assuming) that the defense presented relevant brain damage evidence during trial?

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65 Id.

66 See Kaplan, 20 Stan L Rev at 1078–82 (cited in note 23) (discussing the value of compromise verdicts for a lesser included offense in criminal trials).

67 McGrayne, *The Theory That Would Not Die* at 6 (cited in note 28) (noting that Bayes's "ingenious solution" to finding data for his formula was this: "As a starting point he would simply invent a number—he called it a guess—and refine it later as he gathered more information.").

The Bayesian posterior probability will substantially differ from the prior probability. More specifically, while the prosecutor knows with certainty ($P(B) = 1.0$) that the defense will present relevant brain damage evidence on retrial, the prosecutor does not know what impact that evidence will have. Rather than gamble on an acquittal, for example, the prosecutor accepts a plea agreement. Expressed numerically in Table 1:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{(0.15) \cdot (0.50)}{0.25} = 0.30 = 30\%$$

The probability of a murder conviction in New York State in cases in which the defense presents brain damage evidence probative of culpability during trial is substantially lower than in those cases in which the defense did not present brain damage evidence (30 percent compared to 50 percent). Therefore, it can be argued that the defense's ability to present brain damage evidence probative of culpability updated the prosecutor's prior belief—that a jury could likely convict Jones of murder—to a posterior belief that a jury could possibly acquit Jones. For that reason, the prosecutor offered a compromise solution, enabling Jones to plea bargain down to manslaughter.

Presumably, such an approach allows individuals to recalculate the validity of their beliefs based on the best available evidence, in this case, the more personalized and modern neuroimaging evidence. In theory, an individual's initial beliefs about a defendant's behavior, plus new evidence, equals a new and improved understanding. The more alternative explanations that exist for the defendant's behavior, the less plausible an individual's initial beliefs may be until those alternative explanations no longer make a difference. Applied in a legal context, a Bayesian approach suggests that, if legal actors—such as judges, juries, prosecutors, and defense attorneys—do not rigorously consider alternative explanations for a defendant's behavior, the best available evidence will simply confirm their initial belief even if that belief was biased, uncertain, or ill-informed. In sum, Bayesian statistics help individuals reduce their uncertainty through rational, calculated probabilities.[68]

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[68] See O'Reilly, Jbabdi, and Behrens, 35 Eur J Neuroscience at 1169 (cited in note 46).

C. Neuroscientific Information

This Essay employs a Bayesian approach for several reasons. First, there is evidence that such a probabilistic worldview is consistent with how the human brain operates and the way that individuals try to make sense of their surroundings. All individuals attempt to construct their beliefs about their circumstances by interpreting the many competing and ambiguous signals that they process continuously throughout every moment of their lives. These constructions are based on an individual's prior knowledge, experiences, and beliefs in addition to any new information and evidence that can update that person's conclusions and hypotheses.[69] Defendants such as Jones, however, may be impaired in their ability to construct their beliefs because of their cognitive deficiencies. As a result, their perceptions may not be reasonable.

A probabilistic approach for assessing both reasonable and unreasonable beliefs is especially appealing in the realm of neuroscientific evidence as it relates to environmental and sociological factors. For example, enhanced personalization can help counter the simplistic, all-or-nothing assumptions about neuroscience in court cases[70] because it brings in many different types of neuroscience tests and measures that may be relevant in a particular case, as Part IV of this Essay demonstrates with criminal defenses. These measures include an extensive range of variables concerning a defendant's neighborhood, early trauma, and home life, which are extremely important influences on human behavior. Separately and interactively, cumulative probabilities of all these variables help to explain a particular result or behavior rather than allow neuroscience alone to carry exclusive or even maximal weight. Bayesian analysis is a particularly fruitful way of individualizing criminal law.

Next, Bayesian Theory can override other kinds of wrongheaded theories that courts rely on when they are evaluating neuroscientific evidence. For example, a substantial number of courts turn to a "double-edged sword" analysis when deciding the admissibility of a neuroscientific test or argument.[71] Such an analysis assumes that the defendant's brain is "too broken" and the defendant "too dangerous to have at large," even if he is "somehow

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69 See Kording, 25 Current Op in Neurobiology at 130–33 (cited in note 46).

70 See Denno, 56 BC L Rev at 496–99 (cited in note 22).

71 See id at 529–31.

less culpable."[72] The double-edged approach also mistakenly believes that neuroscientific evidence will either get defendants off the hook entirely or inaccurately paint them as an undeterred danger to society. Yet there seems to be no basis for such an understanding, especially when the defense nearly always wants to present the evidence and the prosecution nearly always wants to exclude it.[73] With rare exceptions, for both sides, the evidence is typically considered mitigating and works to the defendant's benefit or else has no impact whatsoever.[74]

A Bayesian emphasis on alternative hypotheses and improved beliefs balances out a common approach, taken by the *Jones* trial court, to cap the amount of evidence to be considered in any one case. In *Jones*, the trial court determined that the nonimaging tests were sufficient indicators of Jones's level of cognitive impairment. In contrast, the defense successfully argued on appeal that the results of MRI and CT testing would introduce a more refined understanding of Jones's mental challenges. Excluding this imaging evidence eliminated one of the most reliable indicators of Jones's condition and perhaps an entirely new explanation for his behavior (or at least an improved one). The prosecution's ultimate decision to plea bargain in Jones's case likely reflected some concern that a jury may view the MRI and CT scan evidence as mitigating or, at the very least, that the prosecution did not want to take that chance.

Lastly, and perhaps most significantly, a Bayesian approach can help cut through the Gordian Knot that grips neuroscience debates academically and filters into the real world of litigation. Is criminal behavior based on free will or determinism? Should neuroscience be viewed through the eyes of philosophers or scientists, defense attorneys or prosecutors? If scientists, from which fields? These questions recognize the vast tugs-of-war between psychologists, physicians, and neuroscientists and the training, beliefs, interpretations, causal presumptions, biases, and testing that each field brings with it. How large a role does or should neuroscience play in the criminal justice system? Is the evidence

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72 Jones and Shen, *Law and Neuroscience in the United States* at 362 (cited in note 15) (discussing the particularly misplaced assumptions about neuroscience in the death penalty context) (emphasis omitted).

73 See Denno, 56 BC L Rev at 496–99 (cited in note 22) (discussing the pervasive influence of the double-edged sword analogy in court cases).

74 Id at 543–44.

undeservingly pronounced or insufficiently recognized, and how broad should the parameters be for its relevance?

Such legal and interdisciplinary debates are beyond this Essay's scope, and they have been thoroughly discussed elsewhere.[75] Yet while they are critically important to understanding the links between neuroscience and law, they can also mire the examination of neuroscientific evidence in real cases, in which the issues require not weighty musings but quick resolution. After all, an appeal of Bayesian Theory is its capacity to deal with uncertainty—which is also the reigning framework for law and neuroscience debates. We now know far more about what explains human behavior than we ever have, but more questions remain than anyone can definitively answer.

D. Normative Questions and Criticisms

The use of probability analysis in legal cases is not new, of course. Nor is Bayesian theory new to law, although its impact has been far vaster in other fields. In 1968, Professor John Kaplan introduced the application of a Bayesian approach to law and enhanced personalization in a discussion of the virtues of subjectivity and a "personalistic definition of probability [whereby] different people may have different ideas about the probability of the same event."[76] Others would follow, including Professor Laurence Tribe's torrid criticisms of the Bayesian approach.[77] Tribe stressed that the application of Bayes's Theorem to the trial process can often be, at best, limited, and, at worst, distortive and error-ridden. He noted that the approach conflicted with other values that the legal system serves and made the "system seem even more alien and inhuman than it already" appeared.[78] Indeed, other legal commentators have emphasized that "classical statistical methods," over Bayesian theory, have been the more popular choice for analyzing legal proceedings and problems.[79]

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75 For an excellent overview of many of these conflicts—regardless of which sides a reader may take, see generally Alces, *The Moral Conflict of Law and Neuroscience* (cited in note 47).

76 Kaplan, 20 Stan L Rev at 1067 (cited in note 23).

77 See generally Tribe, 84 Harv L Rev 1329 (cited in note 57) (providing a negative view of a Bayesian approach in law). But see generally Finkelstein and Fairley, 83 Harv L Rev 489 (cited in note 57) (providing a positive view of a Bayesian approach in law).

78 Tribe, 84 Harv L Rev at 1376 (cited in note 57).

79 See, for example, Norman Fenton, Martin Neil, and Daniel Berger, *Bayes and the Law*, 3 Ann Rev Statistics & Application 51, 52 (2016).

Perhaps the most recognized critique comes from Professors Daniel Kahneman and Amos Tversky's famous article on subjective probability—which assailed the Bayesian approach[80]—as well as Kahneman's further criticisms in his book, *Thinking, Fast and Slow*.[81] While this body of work is beyond this Essay's scope, it bears emphasizing that critics of Kahneman have challenged both the veracity and replicability of some of the key research on which he relied in his critiques of the Bayesian approach, as well as his assertions on their merits.[82]

Indeed, Kaplan's original article reminds us that the applicability of a Bayesian approach to the criminal justice system does not need to meet the same expectations as the hard sciences and that probabilities are a greater indication of the truth than intuition. The surge in use of a Bayesian approach in recent years in

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[80] Daniel Kahneman and Amos Tversky, *Subjective Probability: A Judge of Representativeness*, 3 Cognitive Psychology 430, 449–52 (1972).

[81] Daniel Kahneman, *Thinking, Fast and Slow* 169, 173–74 (Farrar, Straus and Giroux 2011).

[82] Kahneman suggests that reflexively formed cognitive biases can inhibit deliberate rational reasoning, hence the title of his book. See generally id. Critics dispute his notion of irrationality and have suggested that information presented in certain formats allows humans to reason through their own biases. See David R. Mandel, *The Psychology of Bayesian Reasoning*, 5 Frontiers in Psychology 1, 1–2 (Oct 2014); Gerd Gigerenzer and Ulrich Hoffrage, *How to Improve Bayesian Reasoning without Instruction: Frequency Formats*, 102 Psychological Rev 684, 700 (1995). Humans can exhibit this capability from a very young age. See David M. Sobel, Joshua B. Tenenbaum, and Alison Gopnik, *Children's Causal Inferences from Indirect Evidence: Backwards Blocking and Bayesian Reasoning in Preschoolers*, 28 Cognitive Science 303, 330 (2004) (finding that children as young as four years old demonstrated reasoning consistent with a Bayesian model of cognition when confronted with basic sight-puzzles).

In addition, Kahneman's findings support the notion of priming, which suggests that unassuming stimuli can unconsciously affect thoughts and actions; this area of research, however, has recently suffered from a crisis of replication. See Alison Abbott, *Disputed Results a Fresh Blow for Social Psychology*, 497 Nature 16, 16 (May 2, 2013) (reporting that Kahneman himself has challenged researchers to be more careful in replicating priming studies). The turmoil is due, in part, to academic scandal, as at least one prominent scholar in the area was implicated in a 2012 case of research fraud at Dutch universities. See Daniel Engber, *The Irony Effect: How the Scientist Who Founded the Science of Mistakes Ended Up Mistaken* (Slate, Dec 21, 2016), archived at http://perma.cc/L2T7-PLJL (noting that, while Kahneman's research did not face questions of integrity, one scholar in the area was accused of falsifying results while another foundational theory in the field of priming was widely debunked); Ulrich Schimmack, Moritz Heene, and Kamini Kesavan, *Reconstruction of a Train Wreck: How Priming Research Went off the Rails* (Replicability-Index, Feb 2, 2017), archived at http://perma.cc/KU5S-JP59 (quantifying concerns on replicability and noting that findings on priming should not be construed as scientific evidence). Kahneman responded to Schimmack, Heene, and Kesavan in the comments to their piece, stating that he "put too much faith in underpowered studies." Schimmack, Heene, and Kesavan, *Reconstruction of a Train Wreck* (cited in note 82).

a broad range of disciplines,[83] as well as its suggested application to neuroscientific information in particular,[84] provides a more modern perspective on current thinking.

Most significantly, a Bayesian approach is an effective vehicle for allowing a decisionmaker to consider a wide array of information about a defendant in the context of a personalistic theory of probability.[85] This focus raises normative considerations and two questions in particular that pertain specifically to neuroscientific evidence: If presenting more neuroscientific evidence makes $P(A|B)$ less than $P(A)$ by a certain margin, shouldn't courts favor admitting such evidence rather than excluding it? This question is different from the basic question of whether such evidence is probative and not unduly prejudicial because some courts will exclude neuroscientific evidence if they think it simply will not be necessary, regardless of whether it is prejudicial.

If presenting more neuroscientific evidence reduces the level of initial "prior" bias that a judge or jury may have toward or against a defendant for nonlegal reasons (for example, race), shouldn't courts favor admitting neuroscientific evidence rather than excluding it? This question is especially important in light of research indicating a strong degree of implicit bias on the parts of judges, juries, and other legal actors.[86]

These questions go to the core of the overlap between personalization and the clarifying effect of Bayesian updates because a probabilistic approach allows for greater individualization of the court's treatment of a defendant. They also highlight the utility of a probabilistic approach in circumstances in which personalization is especially important, such as the use of neuroscientific evidence in criminal defenses.

III. A PERSONALIZED APPROACH TO DEFENSES

In my Neuroscience Study, the intersection between neuroscience, social and environmental factors, and criminal law overlaps perhaps most pointedly at criminal law defenses. There, defense attorneys rely on the science either to diminish culpability and

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[83] See, for example, Fenton, Neil, and Berger, 3 Ann Rev Statistics & Application at 52–53 (cited in note 79); Klarreich, 58 Communications of the ACM at 21–22 (cited in note 56).

[84] See, for example, Kording, 25 Current Op in Neurobiology at 131–32 (cited in note 46); O'Reilly, Jbabdi, and Behrens, 35 Eur J Neuroscience at 1172–78 (cited in note 46).

[85] See Kaplan, 20 Stan L Rev at 1067 (cited in note 23).

[86] See, for example, Jerry Kang, et al, *Implicit Bias in the Courtroom*, 59 UCLA L Rev 1124, 1135–50 (2012) (analyzing the extensive research on implicit bias).

therefore mitigate the sentence (as in *Jones*) or to suggest that the defendant was so incompetent or insane that he could not understand the nature of his thoughts or actions. The following Sections focus on the use of Bayesian Theory as a normative model and how courts can—and sometimes already do—incorporate neuroscientific evidence and a personalized approach.

A. The Defense of Dismissing or Diminishing the Defendant's Level of Mens Rea

The Neuroscience Study found that a common tactic used by defense attorneys is to argue that defendants did not have the requisite mental state to commit the crimes for which they were convicted; in other words, their mental state at the time of the crime was below the legal requirement (a lesser mens rea) because of some kind of cognitive deficiency. Jones's contention that his cognitive injuries impaired his ability to form an intent to kill Hardaway is a variant of this tactic. Therefore, Jones argued, he did not deserve a murder conviction but rather a charge more fitting with his diminished culpability, such as manslaughter.

In my Neuroscience Study, eighty-one lesser–mens rea cases were divided into two categories, as Figure 1 shows: (1) thirty-nine capital cases and (2) forty-two noncapital cases. Because I have examined the thirty-nine capital cases elsewhere,[87] the discussion here focuses on the noncapital cases, although comparisons between the two categories are helpful because courts fail to provide clear guidelines for both types of cases, and they have many parallels. The lesser–mens rea defenses for both categories (capital and noncapital) were also comparably successful, although slightly more so for noncapital cases. For example, in the thirty-nine capital cases, ten defendants—or one-quarter (25.64 percent)—were successful; in the forty-two noncapital cases, thirteen defendants—or nearly one-third (30.95 percent)—were successful. Success was defined as defendants winning an argument for a lesser mens rea, thereby reversing their convictions or sentences on appeal.

Whether a lesser–mens rea case is successful may be based in part on a personalized Bayesian perspective—specifically, the opportunities that defendants have to present to triers of fact alternative explanations and hypotheses for their lesser mens rea. The vagueness of the mens rea categories—as well as the nature

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87 Denno, 85 Fordham L Rev at 461–72 (cited in note 49).

and extent of the neuroscientific and socio-environmental variables that may also be relevant—invite a wide variety of interpretations of what a defendant was thinking. Furthermore, the evidence and testing can vary enormously.[88]

In *People v Cegers*,[89] for example, the defendant "was convicted of assault with a deadly weapon, use of a dangerous and deadly weapon, and intentional infliction of great bodily injury."[90] However, because the trial court concluded there were mitigating circumstances, it chose a lower sentence of just two years in prison.[91] Yet the defendant appealed, claiming that the trial court erred by excluding expert testimony related to his brain functioning.[92] The appellate court agreed.[93]

The defendant's principal contention on appeal was that the trial court should have allowed expert testimony related to sleep disorders that, the defendant alleged, influenced his behavior and negated his intent.[94] According to the Court of Appeal, exclusion of expert testimony that the defendant suffered from "confusional arousal syndrome" was reversible error.[95] Confusional arousal syndrome is found in individuals suffering from sleep apnea and who awaken during a state of depressed mental functioning.[96] Due to a brain anomaly, such individuals can engage in motor functions such as sleepwalking and sometimes "can be violent, causing injury or death to others."[97] The expert evidence supporting the presence of this condition was extensive and raised a number of probabilistic associations that could be jointly or sequentially incorporated into a Bayesian model—ranging from an electroencephalogram (EEG) test, a sleep history, administration of an all-night test of oxygen in defendant's blood using an oximeter test, and examination of the defendant's breathing patterns.[98]

As the appellate court stressed, all of the testing was highly personalized: "[T]he doctor's approach was specific to [the defendant], based upon a personal examination, the taking of a history,

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88 See id at 455.
89 7 Cal App 4th 988 (1992).
90 Id at 990–91.
91 Id.
92 Id.
93 *Cegers*, 7 Cal App 4th at 991.
94 Id.
95 Id at 993–95.
96 Id at 993.
97 *Cegers*, 7 Cal App 4th at 993.
98 Id at 1000.

the measuring of blood levels during sleep, and a consideration of the unique facts of the assault."[99] In addition, the court viewed these factors in terms of a probabilistic framework. As the court explained, "It was, in fact, garden variety medical/psychological testimony concerning the probable physiological defect to which [the defendant] was subject, a defect that would affect his mental state at the time of the assault."[100] Recognizing "the bizarre circumstances of the crime," the court also applied probabilistic reasoning: "[I]t is at least reasonably probable that had the evidence in question been admitted the defendant would not have been found guilty."[101]

B. The Defense of Insanity

The insanity defense has different parameters and expectations than a lesser–mens rea defense, and it would be expected that the Bayesian events that define it would vary as well. For example, the defense is highly controversial, rarely raised, and notoriously difficult to prove.[102] In my Neuroscience Study, however, the defense is a key component of cases using neuroscientific evidence. As Figure 2 shows, altogether 93 of the Neuroscience Study's 553 defendant cases (17 percent) involved an insanity defense.[103] In about half of the insanity cases (forty-seven), the defendant claimed he or she was insane due to a neurological disorder. In the remaining cases, the defendant pointed to other causes, such as a psychiatric or mental illness (twenty-three cases) or organic brain damage (twenty cases).

While all ninety-three cases involved neuroscientific evidence in some way, seventy-one cases included some type of electrophysiological monitoring or neuroimaging, including EEG, MRI testing, CT scans, and single-photon emission computed tomography (SPECT) scans. Neuroimaging evidence was most commonly used to support the presence of organic brain syndrome or organic brain abnormalities (twenty-one cases). In addition, among the

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99 Id.

100 Id.

101 *Cegers*, 7 Cal App 4th at 1001.

102 See Dressler, *Understanding Criminal Law* at 317–18, 336–37 (cited in note 31).

103 In these ninety-three cases, most courts used two different types of insanity tests to evaluate the defense: the *M'Naghten* Rule, which requires that the defendant did not know the nature and quality of the act she committed as a result of a disease of the mind or that, if she did know it, she did not know that what she was doing was wrong; and the MPC Rule, which requires that the defendant lacked substantial capacity to appreciate the criminality of her conduct or to conform her conduct to the law's requirements. Id at 346, 350.

ninety-three defendants, fifty-four different types of diagnoses were identified, the most common being substance abuse, depression, organic brain syndrome, personality disorder, and schizophrenia. In addition, nineteen cases involved a malingering issue—thirteen of which were directly related to the defendant's insanity plea. Notably, approximately one-half of the ninety-three defendants (fifty-five) received the death penalty.

Some scholars have posited that neuroscientific evidence—as opposed to historically used psychiatric evidence—would heighten the likelihood of a successful insanity plea because the evidence should be viewed as more convincing.[104] Yet the Neuroscience Study did not necessarily find such a difference. In only two of the ninety-three cases did the court rule in favor of a defendant who had asserted an insanity defense; in both cases, the defendant was found not guilty by reason of insanity. In three cases, an appeals court ruled in favor of a defendant who claimed ineffective assistance of counsel for reasons related to an insanity defense. Finally, in one case, the defendant's conviction and sentence were reversed due to a procedural error that prejudiced the defendant's ability to argue his insanity defense. In eighty-seven cases, then, the court ruled in favor of the prosecution and the defendant was convicted, or the conviction or sentence were reversed or remanded for reasons unrelated to an insanity defense.

An examination of *Dixon v State*,[105] one of the two cases in which the court ruled in favor of the defendants' claim of insanity, suggests that an insanity defense succeeds when there are seemingly *no* alternative hypotheses whatsoever—zero probability—to explain why a court would not find a defendant insane. When viewed through the lens of a Bayesian approach, then, the range of probabilistic updates for a trier of fact would be highly limited. In *Dixon*, the defendant was convicted of the attempted murder

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104 See, for example, N.J. Schweitzer and Michael J. Saks, *Neuroimage Evidence and the Insanity Defense*, 29 Behav Sci & L 592, 594 (2011):

> [The] concern is that, when jurors are able to "see" the source of behavior in the image of a malfunctioning brain, they will be substantially more persuaded than they have been by traditional forms of testimony such as behavioral descriptions by lay or expert witnesses or explanations of the behavior offered by psychological and psychiatric experts.

See also, for example, Joseph Dumit, *Objective Brains, Prejudicial Images*, 12 Sci in Context 173, 194–98 (1999).

105 668 S2d 65 (Ala Crim App 1994).

of a police officer and sentenced to twenty years in prison.[106] Following the attempt, she was committed to a hospital for treatment because she was found incompetent to stand trial.[107] Although she was then given medications in order to become competent to stand trial, she appealed her conviction and sentence, claiming that the evidence of her insanity was overwhelming, that she had overcome the presumption of sanity, and that she should be acquitted. The appellate court agreed.[108]

The evidence on the appellant's side was extensive. According to an expert's interpretation of her CT scan, at the time of the alleged offense, the appellant evidenced "a psychotic delusional disorder" in which her "thought processes were severely impaired . . . to the extent that she was unable to rationally evaluate and appreciate either her own actions or those of others."[109] Subsequently, "as a result of a severe mental disease or defect [the appellant] was unable to appreciate the nature and quality of the wrongfulness of her acts"—essentially satisfying the requirements of the *M'Naghten* insanity test.[110] Additional evidence followed, such as a stream of prior hospital records, including psychological test results, a social and family history, and a drug test, as well as testimony from a number of doctors affirming the basis of the appellant's delusional disorder.[111]

While the appellant was able to act "normally" at other times, in general she "could not function rationally."[112] The doctor who also interpreted the appellant's CT scan testified that the appellant "really thought she was in danger" from the police officer and "was convinced that what she was doing [to the officer] was appropriate and necessary."[113] Important to the court, and to the value of neuroscientific evidence generally, was the fact that the expert's "opinion about the appellant's mental state was not based primarily on the appellant's description of her own symptoms"[114] but rather on all of the other evidence that was independent of her control; this included "voluminous records outlining the

106 Id at 65.
107 Id at 66–67.
108 Id.
109 *Dixon*, 668 S2d at 67.
110 Id.
111 Id at 68.
112 Id.
113 *Dixon*, 668 S2d at 68.
114 Id at 71.

nearly identical conclusions of four other mental health professionals that the appellant was psychotic."[115] Indeed, the court's view accentuates the significance of neuroscientific evidence on many levels, not the least of which was to show that the defendant was not malingering about her condition. Perhaps most significantly, "[T]here was 'nothing before the jury to rebut the great mass of testimony directly showing actual insanity before, at the time of, and after the act in question.'"[116] As the court emphasized, "[T]here were simply no facts from which opposing inferences might have been rationally drawn."[117]

The insanity defense, then, is particularly restrictive in terms of enabling the defense to present alternative hypotheses. Like *Jones*, it is helpful to examine a case like *Dixon* according to a Bayesian formula to illustrate the extent of these constraints. Suppose the two events at issue in the *Dixon* case are Event A, a person who is able to understand right from wrong, and Event B, a person who has a specific brain abnormality, such as frontal lobe damage. The next step would be to establish the "prior" probability, that is, suppose that there is some information about Event A that the trier of fact initially believes has a probability $P(A)$ of being correct. Let's assume that $P(A)$ is the probability of any given person being able to understand right from wrong, which this example estimates to be 95 percent. Suppose also that new evidence, B, is factored in; this example estimates the probability $P(B)$ of a person having frontal lobe damage to be 10 percent. The question then becomes, what is the probability of a person understanding right from wrong given frontal lobe damage?

Suppose, for example, there is a 5 percent probability $P(B|A)$ of frontal lobe damage given that the person knows right from wrong. The question we would want to answer is the Bayesian "posterior" probability, that is, what is the probability $P(A|B)$ of a person knowing right or wrong given (or assuming) that the person has frontal lobe damage? If the trier of fact's Bayesian updating has occurred, the posterior probability will substantially differ from the prior probability. Expressed numerically, the formula is:

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115 Id at 72.

116 Id, quoting *Herbert v State*, 357 S2d 683, 689 (Ala Crim App 1978).

117 *Dixon*, 668 S2d at 72, quoting *Herbert*, 357 S2d at 689.

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{(0.05) \cdot (0.95)}{0.10} = 0.475 = 47.50\%$$

In this example, the probability of a person understanding right from wrong given frontal lobe damage is about half as likely as in those circumstances in which the person does not have frontal lobe damage (47.5 percent relative to 95 percent). Therefore, it can be argued that the defense's presentation of a defendant's frontal lobe damage should be considered mitigating when the defendant is compared to the rest of the population. A comparable type of analysis could be applied to the defense of incompetency to stand trial given that incompetency and insanity often draw from the same pool of defendants.

C. The Defense of Incompetency

In the criminal context, a defendant's competence is required in order to move forward with standard court procedures. Altogether, as Figure 3 shows, my Neuroscience Study found that sixty-seven cases involved a competency issue. More than half of these cases focused on the question of whether the defendant was competent to stand trial (forty cases), while the others addressed alternative concerns. Yet in only eleven (16.41 percent) of the sixty-seven cases did the court find a reasonable doubt as to the defendant's competency.

In almost half of the competency cases, the defendant claimed he or she was incompetent due to organic brain damage (twenty-seven cases). The remaining cases' claims relied on head trauma or brain injury, psychiatric or mental illness, neurological disorder or impairment, or mental retardation. In addition, nineteen cases noted the possibility of a malingering defendant: strikingly, courts held in more than half of those cases (eleven) that defendants were malingering or feigning an illness.

Over half of the sixty-seven cases (thirty-eight cases or 57 percent) used electrophysiological monitoring (such as EEG tests) or neuroimaging (such as MRI and CT scans). While neuroimaging was most commonly employed to support the presence of a brain injury or brain damage (twenty-two cases), it was also often employed to undermine the presence of such abnormalities, typically with a finding that a defendant's brain was normal.

At the same time, neuroimaging appeared to be a significant factor in competency determinations. Examining these cases

shows some of the personalized information that was involved. In four (18.18 percent) of the twenty-two cases in which neuroimaging supported the presence of a disorder or brain damage, the court found a reasonable doubt of competency. For example, in *Maxwell v State*,[118] an MRI revealed that the defendant had a rare and severe form of multiple sclerosis that caused lesions on his brain, affecting his mental condition.[119] When the trial court was presented with this evidence, it acknowledged that the defendant was incompetent.[120] In *United States v Duncan*,[121] standby counsel produced results from MRI and positron emission tomography (PET) scans showing that the defendant possessed an unusual brain structure.[122] The defense-appointed experts contended that the defendant's brain dysfunction contributed to a severe psychosis that "render[ed] him unable to have a rational understanding of the proceedings or to waive his right to counsel and to represent himself."[123] While the court-appointed experts disagreed, the court held that the evidence was enough to create a reasonable doubt of competency.[124] In *State v Marshall*,[125] the defendant was given MRI, EEG, and SPECT scans, which all showed, according to the defense expert, "[c]lear evidence of brain damage."[126] The court referred to the neuroimaging evidence, which demonstrated serious brain damage, in determining that there was enough evidence to raise a reasonable doubt of competency.[127]

Lastly, in *United States v Sampson*,[128] the court found that counsel should have pursued a competency hearing given evidence of the defendant's mental illness.[129] An MRI and a PET scan showed evidence that the defendant suffered from organic brain damage.[130] Yet in the other seven of the eleven cases that involved a finding of a reasonable doubt of competency, neuroimaging was not used. These results thereby support the Neuroscience Study's contention that collecting a pool of cases that simply look at brain

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118 974 S2d 505 (Fla App 2008).
119 Id at 507.
120 Id at 510.
121 643 F3d 1242 (9th Cir 2011).
122 Id at 1249.
123 Id.
124 Id at 1250.
125 27 P3d 192 (Wash 2001).
126 Id at 196.
127 Id at 199.
128 820 F Supp 2d 202 (D Mass 2011).
129 Id at 246–47.
130 Id at 243.

scans leaves out a substantial portion of brain-injured individuals who never have the benefit of neuroimaging.

D. The Defense of Diminished Capacity

There is no generally accepted legal definition of "diminished capacity"; instead, "courts have employed the concept of diminished capacity in two fundamentally different ways in the determination of guilt."[131] First, courts use diminished capacity "as a basis for admitting evidence concerning the defendant's mental disease, defect, condition or abnormality at the time of the offense to show that the defendant lacked or possessed the required mental state for the crime."[132] Second, courts employ diminished capacity "as a basis for mitigating the seriousness of an offense, because of the defendant's mental disease, defect, condition or abnormality at the time of the crime, in order to render him or her guilty of a less serious offense."[133] As in *Jones*, the evidence could reduce what would otherwise be a murder conviction to manslaughter, or it could be introduced as a mitigating factor in sentencing.[134]

In the Neuroscience Study, as Figure 4 shows, seventy cases involved diminished capacity as a defense or as a basis for mitigating an offense or sentence. In twenty-seven cases, diminished capacity was raised during the guilt phase of the trial, and in twelve cases it was raised during the sentencing phase. Most of these cases (fifty) involved a situation in which diminished capacity was raised as a mitigating factor. However, in other cases (twenty-four), the defense used diminished capacity to argue that the defendant lacked the requisite mental state necessary for the crime. Altogether, sixty of the seventy defendants were given the death penalty.

In twenty-five of the seventy cases (35.71 percent), neuroimaging or electrophysiological monitoring was used, which predominantly involved major tests, such as MRI and EEG. Neuroimaging was most often employed to support a claim of an organic brain syndrome or abnormality as a mitigating factor. Notably, in

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131 David M. Siegel, *The Defense of Diminished Capacity*, in Robert Cipes, Sidney Bernstein, and Irwin Hall, 1B *Criminal Defense Techniques* § 32.01(1)(e) (Matthew Bender & Co 2018).

132 Id. See also Dressler, *Understanding Criminal Law* at 343 (cited in note 31).

133 Siegel, *The Defense of Diminished Capacity* § 32.01(1)(e) (cited in note 131). See also Dressler, *Understanding Criminal Law* at 344 (cited in note 31).

134 See Siegel, *The Defense of Diminished Capacity* § 32.01(1)(a) (cited in note 131).

twenty-one of the seventy cases (30 percent), the defendant asserted a successful claim that related to a diminished capacity argument or defense in some way. Of those twenty-one cases, there were fifteen in which the court ruled in favor of the defendant's claim of ineffective assistance of counsel.

In *Odle v Calderon*,[135] for example, the defendant, James Odle, was convicted of first degree murder of two different people, including a police officer, after he had been drinking and had taken lysergic acid diethylamide (LSD).[136] He brought forth an ineffective assistance of counsel claim, which he won on appeal based on his counsel's failure to present expert testimony at trial related to Odle's mental condition and statutory mitigating factors.[137] The court noted that Odle underwent an EEG test.[138] Even though the exact results from the EEG were not discussed in the district court's opinion, it was implied that the results reflected evidence of Odle's brain damage.[139] The court also noted that Odle's mental deficiency was not subtle—Odle was "missing a piece of his brain the size of a grapefruit" and his brain deficits were obvious.[140] The EEG results corroborated expert and lay witness testimony related to Odle's erratic behavior and brain disorders as well as Odle's mental health records, which indicated that Odle had undergone a lobectomy some time before he committed the charged offense.[141]

Evidence showed that Odle's mental deficiencies commenced in 1973 when he was in a car accident and experienced "severe trauma to his brain."[142] As a result, a surgeon "performed a temporal lobe lobectomy, removing a 3 x 3 x 4 inch piece of his brain . . . [but leaving] just a flap of skin to cover the opening in [Odle's] skull."[143] The surgeon chose to close the opening only when Odle came back over a year later to complain "that his brain was pulsating beneath the skin."[144] The defense expert who administered

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135 919 F Supp 1367 (ND Cal 1996).
136 *People v Odle*, 754 P2d 184, 187 (Cal 1988).
137 *Odle v Woodford*, 238 F3d 1084, 1089 (9th Cir 2001).
138 Id at 1088.
139 See id.
140 Id at 1089.
141 *Odle*, 238 F3d at 1087–88.
142 Id at 1087.
143 Id.
144 Id.

one of the EEGs noted that the results "revealed brain abnormalities consistent with an epileptic seizure disorder."[145] The expert "testified that Odle's brain injury would probably cause behavioral disturbances beyond his control," a diagnosis that "was consistent with Odle's complaints, documented during his hospitalizations, that he often felt unable to control his impulses."[146] While Odle was originally determined to be competent to stand trial, that finding was reversed, and Odle and his lawyers continue to litigate the case.

This kind of evidence in *Odle* was powerful mitigation because of the alternative explanations and hypotheses that it could have provided had the trial attorney introduced it. Presumably, a jury without such evidence would have viewed Odle's violent conduct in an entirely different way that would have been far less mitigating.

IV. WHO SHOULD BE USING A BAYESIAN APPROACH AND WHY

Discussions of Bayesian Theory in the context of personalization should consider who should be using the approach and why. These factors determine the kinds of events, variables, and assigned probabilities that a model (like Table 1) should incorporate. In the context of criminal law defenses, for example, there could be an array of users or consumers—judges, juries, prosecutors, or defense attorneys. While neuroscientific information generally is becoming more precise, so far there are only estimates, if that, about its prevalence in certain populations. That said, a Bayesian approach accommodates this uncertainty through a probabilistic analysis of particular characteristics that are associated with personalization in the criminal justice system, such as a defendant's culpability and cognitive capacity.

A. The Question of Why

A more pertinent question is: Why use a Bayesian approach? This Essay's discussion of criminal defenses shows that attempts to personalize defendants employing neuroscientific evidence generally—much less through Bayesian updating—could overwhelm judges and jurors with too many bits of information and tax an already complicated proceeding. Indeed, recent evidence showing the extent of individuals' heuristic biases might limit the

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145 *Odle*, 238 F3d at 1088.

146 Id.

ability of some criminal justice consumers to adjust rationally in a Bayesian manner. Some may argue that they would be way too stuck on their priors. Events at the scene of a crime and the defendant's actions—not to mention extralegal factors like race—can also inappropriately dominate consumers' depictions about mens rea or the personalized factors that influence it. Others may contend that the advantage of a Bayesian approach is that it highlights information that would otherwise get lost in the litigation scuffle—especially personalized information about the defendant that triers of fact could overlook when presented with other kinds of variables that may be more heuristically appealing.

Commentators recognize that there will always be subjective judgments involved in a Bayesian approach, such as selecting the confidence level a consumer would use to make a decision as well as the questions that consumers want answered. That said, the resurgent interest in Bayesian thinking is based in part on the growing recognition that inroads in computational design have greatly enhanced the "methods for calculating numerical approximations to high-level dimensional integrals [that have] 'liberated Bayesian inference, and made it much more prominent.'"[147] Indeed, in some ways, this Essay's call for a Bayesian approach is also a call for more research and data collection on neuroscientific information, including surveys, in an effort to better construct probabilities and refine estimates.

This Essay also promotes a Bayesian approach to convey the general idea that the rational way for consumers to deal with a defendant's neuroscientific—and more personalized—information is to update their priors based on more information. Essentially, triers of fact should be given the benefit of Bayes's Theorem by having more personalized information accessible to them. We know the probabilistic thresholds that jurors are supposed to reach—beyond a reasonable doubt or preponderance of the evidence, for example—and Bayesian updating allows jurors to more accurately implement those standards. If there is neuroscientific evidence about defendants that can move triers of fact in one direction or the other, then the system should err on the side of including it. Can this proposal of inclusion cut both ways in terms of benefitting both the prosecution and the defense? It could, but that possibility is the risk of accepting the premise of Bayesian updating and the reach for more data.

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147 Klarreich, 58 Communications of the ACM at 23 (cited in note 56).

The criminal law provides a valuable context for considering the use of neuroscientific evidence to improve criminal justice. First and foremost, the application of neuroscientific evidence in criminal cases is an essential aspect of protecting individual rights. The criminal law emphasizes the mental state of the human mind in a way that the civil law does not, and the stakes of a guilty verdict are higher. Yet the process of investigating, introducing, and challenging neuroscientific evidence within the parameters of a criminal courtroom is costly. Many of the criminal cases in the Neuroscience Study's database include a host of experts for both the prosecution and the defense. Further analysis of the Neuroscience Study's data will enable an evidence-based assessment of the involvement of such experts, with the goal of developing a fairer and more cost-efficient system to address the needs of defendants for whom neuroscientific evidence is most relevant.

B. The Problem of Funding

The funding of testing and experts is an issue that arises in many criminal cases, and it pertains to a wide swath of evidence, irrespective of whether it involves neuroscience. That said, as Figure 5 shows, my Neuroscience Study found that 89 of the 553 defendant cases (16.09 percent) specifically raised the matter of funding for neuroscientific evidence. In all eighty-nine cases, the defense submitted a funding request. There were no cases in which the prosecution made a formal request for funding and no references to the court allotting a specific amount of funding to the prosecution.[148] Altogether, seventy of the eighty-nine cases (nearly 80 percent) started out as capital cases, an unsurprising result given the high stakes involved in such cases.

Of the eighty-nine funding cases, there were thirty-four cases in which funding was requested for imaging; in twelve of those thirty-four cases (35.29 percent), the funding request was granted. In addition, there were twenty-two cases in which funding was requested for nonneuroimaging testing; in ten of those twenty-two cases (45.45 percent), the funding request was granted. Lastly, there were sixty-seven cases in which funding was requested to hire an expert and/or furnish expert testimony;

[148] However, there were several cases in which the prosecution moved for a particular test or evaluation to be performed.

notably, in forty-six cases of those sixty-seven cases (68.66 percent), the funding request was granted.

It is difficult to thoroughly investigate the role of funding because so little has been written about this issue. Whether neuroscientific evidence requests are being treated more generously relative to other types of evidence is unknown because there is no other study or documentation available for comparison. Typically, the court lumps together all requested testing and treats it as a composite. Regardless, an overview of the eighty-nine cases is helpful in determining how legislatures and courts distribute the money allotted for defense attorney requests for experts and testing.

For example, Figure 5 shows that the most common type of funding request was for hiring an expert and/or furnishing expert testimony, followed by requests for imaging testing, and lastly, requests for nonimaging testing. Additionally, it appears that funding requests made for experts are more likely to be granted by courts than requests for imaging or nonimaging testing. Notably, funding requests for imaging tests are the *least* likely to be granted. Presumably, the high cost involved in neuroimaging testing is one explanation for the difficulty in receiving court funding for it, although it is not at all clear that it is truly among the most expensive requests. Not surprisingly, claims of ineffective assistance of counsel were behind many of the funding requests. In total, fifty-three of the eighty-nine funding cases (59.55 percent) involved at least one ineffective assistance of counsel claim. Interestingly, there were only two cases in which at least one ineffective assistance of counsel claim was specifically based on counsel's alleged failure to obtain funding from the state.

A common argument about neuroscientific evidence in criminal cases is that there will not be sufficient funds to cover the tests and experts involved. The Neuroscience Study suggests that funding problems may not be as pronounced as is commonly assumed. That said, most of the funding requests do not pertain to neuroimaging tests but rather to experts generally. While the two may be related (the experts are necessary to interpret the imaging), until further information is gathered, it is presumptuous to conclude that inequality in funding is a reason for attorneys not to request neuroscientific testing, even if it is relevant.

CONCLUSION

This Essay contends that a criminal justice system that is more personalized would likely be more effective, efficient, and

fair and that incorporating neuroscience into the factfinding process is a particularly apt vehicle for enhancing personalization. While the greater influx of personalization may raise concerns by some that the criminal justice system may be unable to regulate punishment appropriately, a probabilistic framework is one way to sidestep these potential problems. Bayes's Theorem is particularly geared toward enhancing personalization and diminishing heuristic biases that legal actors are apt to possess. Likewise, both personalization and a Bayesian approach can help promote a criminal justice system that not only protects society from crime but also punishes criminals at the level of their blameworthiness.

APPENDIX

TABLE 1: APPLICATION OF BAYES THEOREM TO *PEOPLE V JONES*

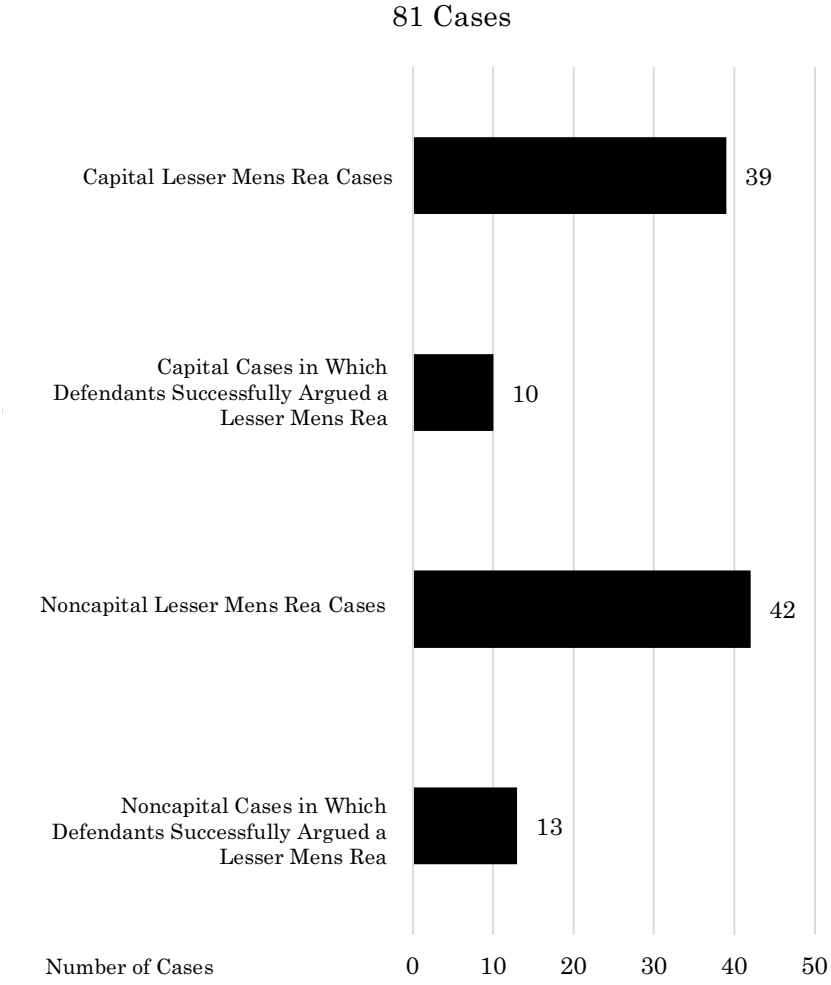
Equation: $P(A|B) = \frac{P(B|A)\cdot P(A)}{P(B)} = \frac{(0.15)\cdot(0.50)}{0.25} = 0.30 = 30\%$

Variables and Assigned Values:

Variable	**What the variable means in the standard equation**	**What the variable means in the applied equation**	**Assigned probabilities**
A	Event A	Murder conviction	—
B	Event B	Defense presents brain damage evidence in court	—
P(A)	Probability of Event A's Occurrence	Probability of a murder conviction (among those charged with murder)	0.50 (50%)
P(B)	Probability of Event B's Occurrence	Probability of the defense's presentation of brain damage evidence (in any criminal case during trial)	0.25 (25%)
P(B | A)	The probability that Event B occurs, given that Event A has occurred (that is, the probability of Event B conditioned on Event A)	The probability that the defense presented brain damage evidence during trial, given (or assuming) that the defendant was convicted of murder (that is, in all the cases in which a defendant was convicted of murder, what was the probability that the defense presented brain damage evidence)	0.15 (15%)
P(A | B)	The probability that Event A occurs, given that Event B has occurred (that is, the probability of Event A conditioned on Event B)	The probability of a murder conviction (among those charged with murder) given (or assuming) that the defense presented brain damage evidence during trial	*This is what we want to find out*

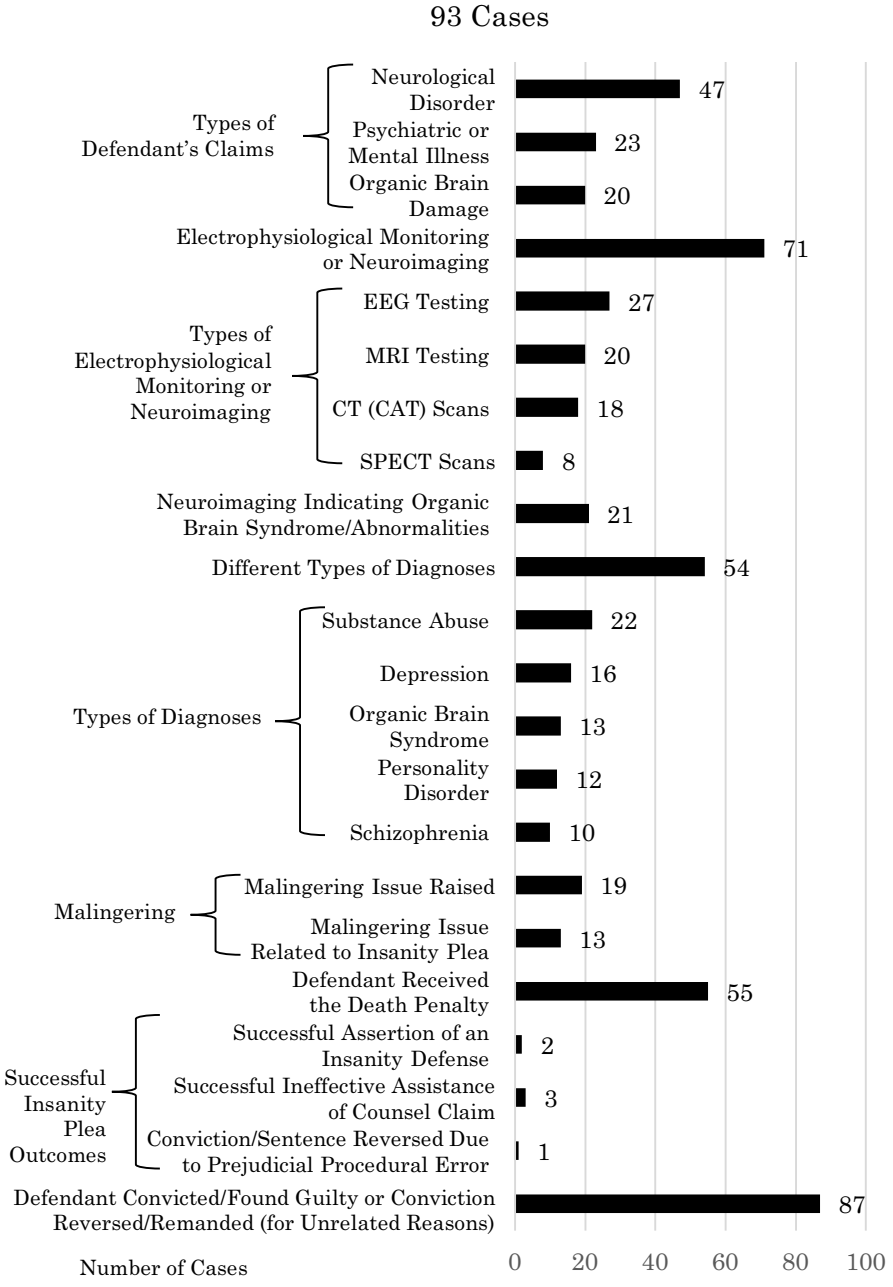
Finding: The probability of a murder conviction in cases in which the defense presents brain damage evidence during trial is substantially less than in those cases in which the defense did not present brain damage evidence (30 percent relative to 50 percent).

FIGURE 1: CHARACTERISTICS OF LESSER MENS REA DEFENSES (BY NUMBER OF CASES)*



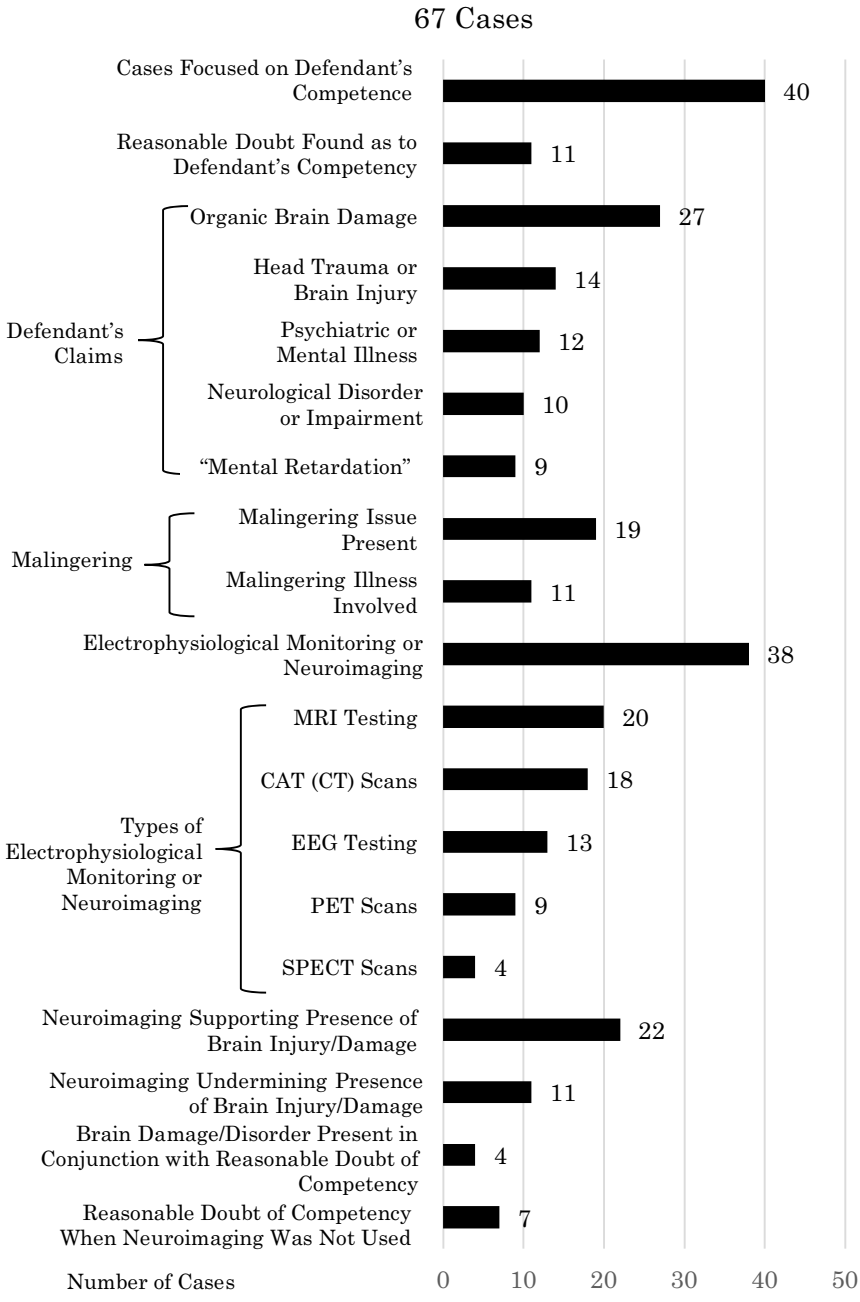
*Categories are mutually exclusive.

FIGURE 2: CHARACTERISTICS OF INSANITY DEFENSES (BY NUMBER OF CASES)*



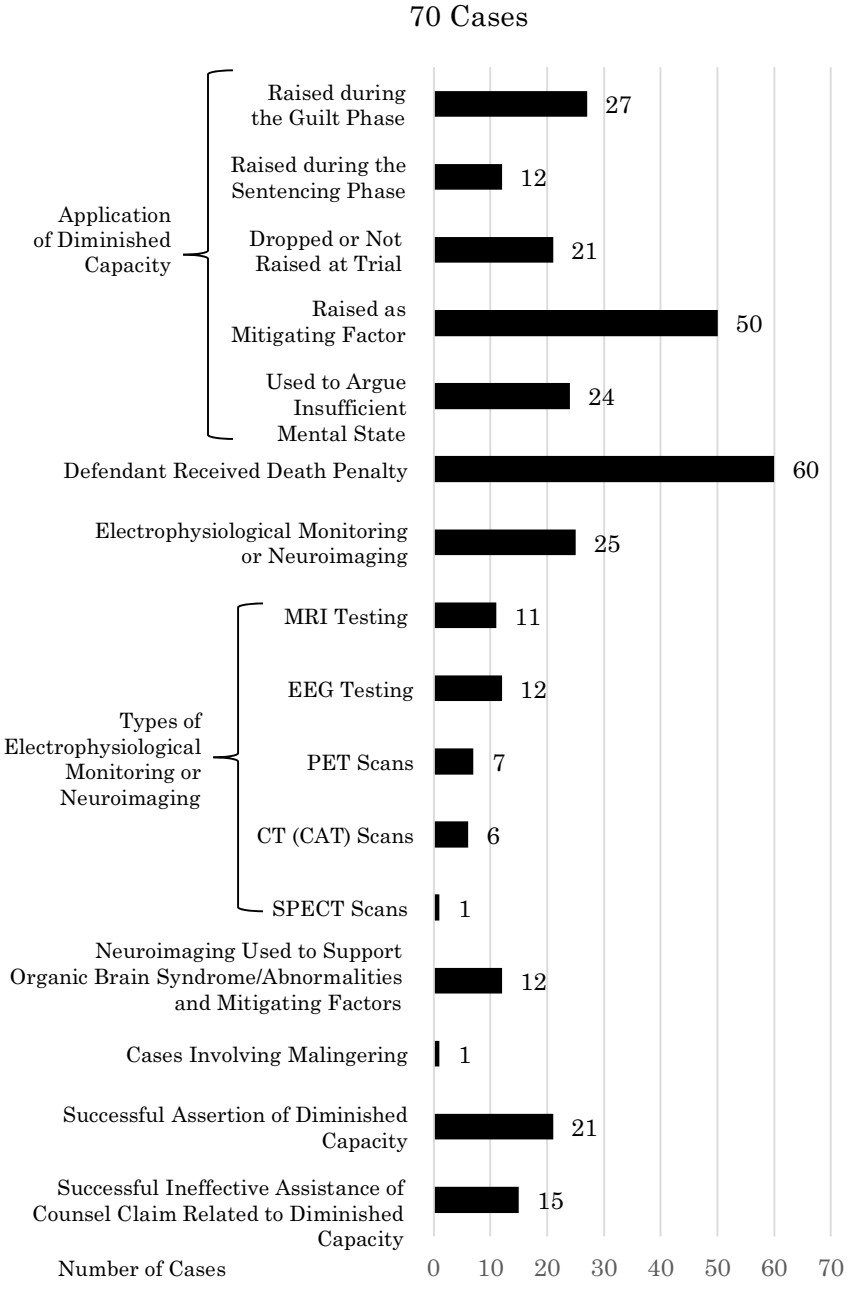
*Categories are not mutually exclusive.

FIGURE 3: CHARACTERISTICS OF INCOMPETENCY DEFENSES (BY NUMBER OF CASES)*



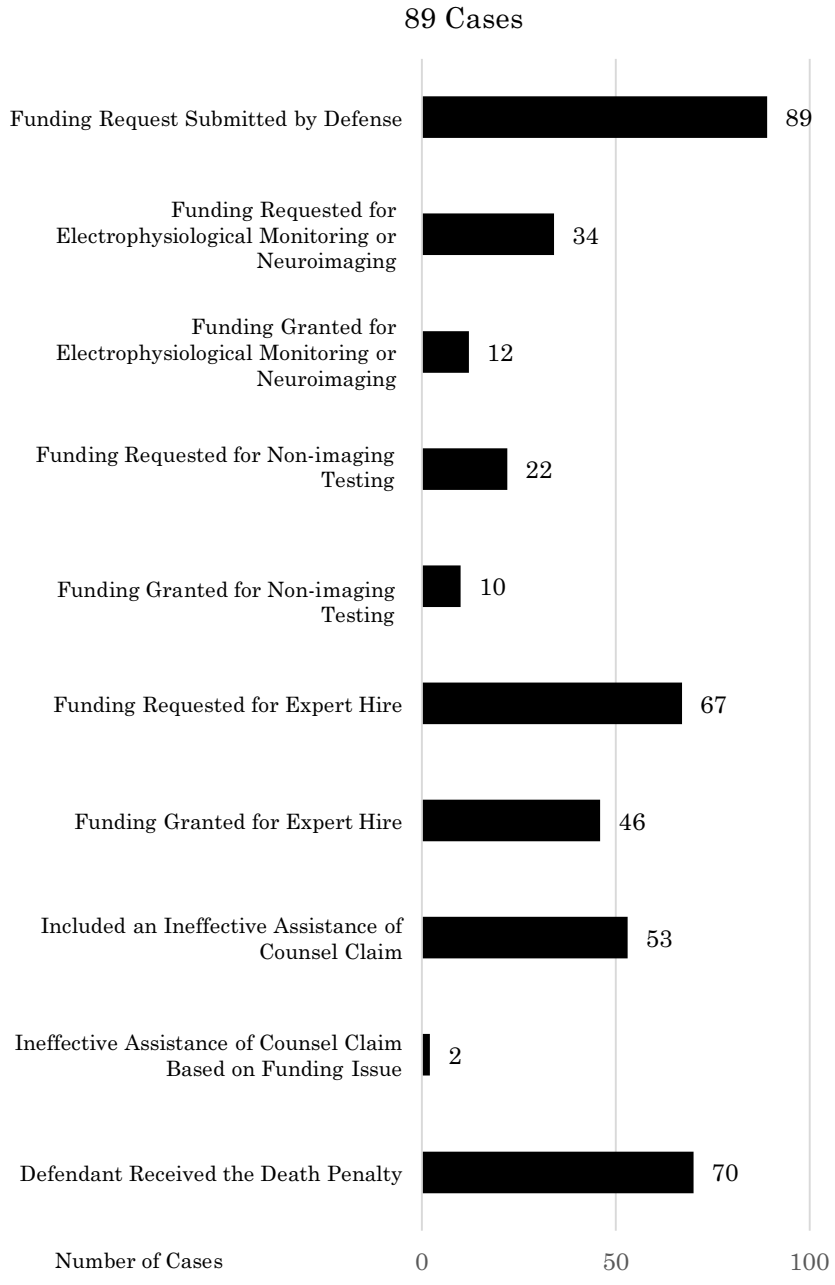
*Categories are not mutually exclusive.

FIGURE 4: CHARACTERISTICS OF DIMINISHED CAPACITY DEFENSES (BY NUMBER OF CASES)*



*Categories are not mutually exclusive.

FIGURE 5: FUNDING ISSUES, REQUESTS AND GRANTS (BY NUMBER OF CASES)*



*Categories are not mutually exclusive.