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The Future of Law and Neuroscience

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THE FUTURE OF LAW AND NEUROSCIENCE

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ABSTRACT

I was asked to speculate about where the field of Law and Neuroscience may be ten years from now. In that spirit (and while recognizing that the future rarely complies with our predictions) I attempt here some extrapolations. I first consider potential advances in the technologies for monitoring and manipulating brain states, the techniques for analyzing brain data, and the efforts to further integrate relevant fields. I then consider potential neurolaw developments relevant to: (1) detecting things law cares about; (2) individualizing developmental states and brain states; (3) evidence-based legal reforms; (4) legal decision-making; and (5) brain-brain interfaces.

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I also thank Jeffrey Schall, and *Research Network* members Richard Bonnie, B.J. Casey, Andre Davis, David Faigman, Morris Hoffman, Read Montague, Stephen Morse, Marcus Raichle, Jennifer Richeson, Elizabeth Scott, Francis Shen, Laurence Steinberg, Kim Taylor-Thompson, Anthony Wagner, and Gideon Yaffe, for the years of fruitful interdisciplinary neurolaw collaboration that informed the views expressed here. Eyal Aharoni provided important feedback on portions of the text. And Greg Maczko, Jonathan George, Jamie Michael, and Divya Bhat provided helpful research assistance. Thanks, too, to the *Evolutionary Studies Initiative* at Vanderbilt University. This work was supported, in part, by the John D. and Catherine T. MacArthur Foundation, and the Glenn M. Weaver Foundation.

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INTRODUCTION

The hosts of this Symposium asked presenters to offer their opinions about what might be happening in Law and Neuroscience ten years down the road. We must obviously approach the question with some humility. Because—despite remarkable discoveries in the brain sciences over the last couple decades—there's so much more that we don't know about the brain than that we do.

So this is a highly fraught exercise. And one that challenges us to somehow free our imaginations, while keeping our feet planted firmly on the ground. In that spirit, and with full recognition of how rarely the future chooses to comply with our predictions, I will attempt to extrapolate into this new future, as asked, in a few of the many important domains of Law and Neuroscience.

Before turning to the future, though, a few words on the past. The late Margaret Gruter, who founded the Gruter Institute for Law and Behavioral Research,[1] deserves a lot of credit for being—so far as I am aware—the first person to bring legal scholars, judges, evolutionary biologists, and neuroscientists together systematically. Margaret believed that the science of animal behavior was relevant to the science of human behavior, and that—if that were true—it would inevitably have implications both for brain sciences generally and for law specifically.

My own interests in animal behavior were sparked at a very young age, by informal observations among woods and lakes, and also by the fascinating books on animal behavior emerging at the time. My interests in law sparked later, in college. And I was not yet aware of Margaret's efforts when I wrote a college paper combining those interests on the relevance of behavioral biology to law. I then went to law school hoping I might be lucky enough to shape an

1. GRUTER INST., http://gruterinstitute.org/ [https://perma.cc/HA7B-EEVR]. Margaret's papers are, along with Richard D. Alexander's, among the earliest known works arguing that the effects of evolutionary processes on the brain, as revealed in the structure and functioning of its neurons, are relevant to law. *See* Margaret Gruter, *Law in Sociobiological Perspective*, 5 FLA. ST. U. L. REV. 181 (1977); Margaret Gruter, *The Origins of Legal Behavior*, 2 J. SOC. & BIOLOGICAL STRUCTURES 43 (1979); Richard D. Alexander, *Natural Selection and Societal Laws*, *in* 3 MORALS, SCIENCE, AND SOCIALITY 265 (H. Tristram Engelhardt, Jr. & Daniel Callahan eds., 1978).

academic career at that intersection. So I was delighted to learn of the Gruter Institute and to meet, through it, others with interests at this same intersection.

Margaret fostered a consistently rich exchange of ideas, typically in intimate conferences at Squaw Valley, California (many of which I attended, some of which I co-directed, and all of which I found illuminating). There, among the peaks of the Lake Tahoe region, we'd give presentations across the disciplinary divides, bat ideas around for days, and share meals, hikes, questions, and findings together.

As it happens, Stanford biologist and MacArthur Foundation Fellow Robert Sapolsky (a co-panelist for this Symposium) attended some of these Gruter Institute events. Which perhaps crucially influenced his response, years later, to then-President Jonathan Fanton's invitation (extended to MacArthur Fellow scientists) for important "big ideas" that the MacArthur Foundation might consider supporting financially, to help jumpstart.

Sapolsky proposed that the Foundation go big on the intersection of Law and Neuroscience. And I, having been working at the law/biology intersection for (at that point) roughly fifteen years, and having recently begun a neurolaw brain-imaging experiment at Vanderbilt University with neuroscientist Rene Marois, was asked to be among the reviewers of the Sapolsky proposal (a fact the Foundation tells me I'm at liberty to disclose). Apparently enough of us reviewers were enthusiastic about the importance of aiding the legal system's inevitable encounters with neuroscience that the Foundation decided to devote considerable resources to this nascent interdisciplinary field.

It would be hard to overstate the importance of the MacArthur Foundation in stimulating national—and later international—work at the law/neuroscience intersection. The Foundation made two major independent, but topically related, investments totaling roughly fifteen million dollars. The first was in the *MacArthur Foundation Law and Neuroscience Project* (Michael Gazzaniga, director), of which I served as a co-director and later director. The second was in the *MacArthur Foundation Research Network on Law and Neuroscience*, which I had the honor to design and direct.[2]

2. For further history of the Foundation's key role in seeding developments in this field, of the underlying legal and technological developments helping to drive progress at the

There isn't room here to do justice to each individual, each collaborative team, and each larger working group that through hard and regular work helped develop common concepts and vocabulary, build bridges, explore implications, discover limitations, pilot projects, co-design experiments, and co-write and co-publish the results across the last two decades.[3] But it's fair to say that a great many prominent scholars, across many of this country's most prominent universities, together with a number of accomplished and deeply thoughtful judges, worked in common enterprise on this entirely new frontier—which had been occasioned, in part, by the intersection of law's perennial questions about responsibility, veracity, memory, and the like with new brain-imaging technologies that enabled the noninvasive study of brain function and decision-making in human subjects.

Although so much has been accomplished to date, the task assigned to us today (against the background just told) is to think about the future. To get started, I want to spend a few moments, in Part I, discussing what I think we're likely to see coming from the science side of things in the next ten years. I'll then offer, in Part II, some remarks about potential futures in five of the many categories of contexts in which neuroscience may offer value to the legal system. They are: (1) detecting things law cares about, (2) individualizing developmental stages and brain states, (3) evidence-based legal reforms, (4) legal decision-making, and (5) brain-brain interfaces.

I. NEUROSCIENCE

Here I'll give examples of potential developments of three sorts, across three Sections. I'll discuss technologies for monitoring and manipulating brains, techniques for analyzing data collected from

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intersection, and of the growth of the field, see Owen D. Jones & Anthony D. Wagner, *Law and Neuroscience: Progress, Promise, and Pitfalls*, *in* THE COGNITIVE NEUROSCIENCES 1015 (David Poeppel et al. eds., 6th ed. 2020).

3. For overviews of neurolaw, see *id.*; OWEN D. JONES ET AL., LAW AND NEUROSCIENCE (2d ed. 2021); Owen D. Jones, *Seven Ways Neuroscience Aids Law*, *in* NEUROSCIENCES AND THE HUMAN PERSON: NEW PERSPECTIVES ON HUMAN ACTIVITIES 181 (Antonio M. Battro et al. eds., 2013).

and about the brain, and theoretical advances from the continued integration of relevant fields.[4]

A. Technologies for Monitoring and Manipulating Brain States

2018 marked a significant achievement in neuroscience, by which researchers managed to compile an extremely detailed brain map of every single synapse in the entire brain of a fruitfly.[5] Obviously there is a massive difference in scale between the diminutive weight of the fruitfly brain, at roughly one-half of one milligram, and the far larger human brain, averaging about 1.35 kilograms (which is therefore roughly 2,700,000 times as heavy),[6] let alone the even much larger brains of elephants and, say, sperm whales, at 4 kilograms and 8 kilograms respectively.[7]

But it does not seem to me at all implausible, given the pace of past neuroscientific and computational progress, to think that within the next ten years we might achieve the same synaptic mapping of a human brain. The insights such a map might provide won't speak for themselves, of course. But a map of such fine-grained detail would likely afford us the opportunity to probe those brain data in ways that could lead to some very significant discoveries.

In addition, the recent and tremendous (and at times shockingly troublesome[8]) advances in gene-editing techniques, such as those

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4. For background on existing technologies and techniques, written for a legal audience, see JONES ET AL., *supra* note 3; Owen D. Jones et al., Brain Science for Lawyers, Judges, and Litigants (2021) (manuscript in preparation) (on file with authors). For one recent view of the future of neuroscientific techniques, see MATTHEW COBB, THE IDEA OF THE BRAIN: THE PAST AND FUTURE OF NEUROSCIENCE (2020). For a view stretching fifty years into the future, see Cara M. Altimus et al., *The Next 50 Years of Neuroscience*, 40 J. NEUROSCIENCE 101 (2020).

5. Zhihao Zheng et al., *A Complete Electron Microscopy Volume of the Brain of Adult* Drosophila melanogaster, 174 CELL 730 (2018). For an example of subsequent work mapping circuits in a large part of the fruitfly brain, see Louis K. Scheffer et al., *A Connectome and Analysis of the Adult* Drosophila *Central Brain*, ELIFE (2020), https://elifesciences.org/articles/57443 [https://perma.cc/R3H7-Y9PL]. The fruitfly brain has roughly 100,000 neurons, whereas the human brain has roughly 86 billion neurons (that is, 860,000 times as many). *Id.*

6. On the weights of fruitfly and human brains, respectively, see Warren Burggren et al., *Metabolic Rate and Hypoxia Tolerance Are Affected by Group Interactions and Sex in the Fruit Fly (*Drosophila Melanogaster*): New Data and a Literature Survey*, 6 BIOLOGY OPEN 471, 472 (2017); FRANS DE WAAL, ARE WE SMART ENOUGH TO KNOW HOW SMART ANIMALS ARE? 123-24 (2016).

7. DE WAAL, *supra* note 6, at 123.

8. *See* HENRY T. GREELY, CRISPR PEOPLE: THE SCIENCE AND ETHICS OF EDITING

using CRISPR, suggest that, across the next ten years, researchers will start genetically manipulating brain form and function in animal models. To the extent those animal models may be from species that have close, common evolutionary underpinnings with our own species, this suggests a tremendous avenue for discovery, some of it potentially law-relevant, about the human condition. And also about the extent to which such techniques might someday be used in humans, to good effect.

With respect to Brain Machine Interfaces, we've seen a lot of development over the last decade in their use in medical contexts, often with paraplegics. Some techniques implant an array of sensing electrodes on the surface of the brain—in the area of the motor cortex, for instance—and connect it to a wireless transmitter, powered by a simple watch battery tucked beneath a flap of scalp skin.[9] This enables people to control the movements of a robot, with remarkably fine precision, simply by manipulating their thoughts alone.[10] I believe we'll see more widespread use, with finer and finer sensitivities and controls, in the next ten years.

I also expect considerably expanded use of technologies to monitor not just the hemodynamic (blood flow) responses in the brain, but also the deeper brain electrical signals (which are not reliably monitored by electroencephalograph (EEG) scalp monitors) and the neurotransmitters active between synapses. These latter two capabilities are currently being achieved by Epilepsy Monitoring Units (EMUs), which are surgically implanted in patients with epilepsy.[11] Some of those patients have begun serving as subjects in research studies. And the ability to supplement fMRI and PET brain imaging with deep brain monitoring of electrical and neurotransmitter monitoring promises to enrich our understanding of brain function.

HUMANS (2021) (addressing issues surrounding gene editing, including safety, coercion, equity, diversity, and enhancement).

9. John P. Donoghue, *New Interfaces for the Brain*, *in* NEUROSCIENCES AND THE HUMAN PERSON: NEW PERSPECTIVES ON HUMAN ACTIVITIES 287 (Antonio M. Battro et al. eds., 2012).

10. For more in this vein, see Moises Velasquez-Manoff, *The Brain Implants That Could Change Humanity*, N.Y. TIMES (Aug. 28, 2020), https://www.nytimes.com/2020/08/28/opinion/sunday/brain-machine-artificial-intelligence.html [https://perma.cc/2WL4-ECDP].

11. *See, e.g.*, *Epilepsy Monitoring Unit*, JOHNS HOPKINS MED., https://www.hopkinsmedicine.org/neurology_neurosurgery/centers_clinics/epilepsy/emu.html [https://perma.cc/P5TM-GCW5].

These are just some examples of the kinds of technologies in which I expect there to be significant advances over the next ten years, flowing from government programs (such as the Obama White House Brain Initiative[12]), universities, and private industry.

B. Techniques for Analyzing Brain Data

Of course, not all scientific advances are technological in nature. Many are methodological. And I anticipate large leaps in methods used to extract useful patterns and information from the huge amounts of brain data that brain-imaging techniques collect. And much of that will come from the continuing and expanding deployment of artificial intelligence techniques, which are themselves advancing rapidly.

For instance, many teams, including those in the MacArthur Foundation Research Network on Law and Neuroscience[13] (hereinafter Research Network), have begun partnering fMRI brain imaging (which enables inferences on locations and changes in brain activity, during different tasks, on the bases of changes in localized blood flow during tasks) with machine-learning algorithms, including multi-voxel pattern analysis. Machine-learning techniques enable us to ask computer programs to explore the data and to identify patterns that are both (a) identified faster than humans would otherwise be able to do (if at all); and (b) identified by (essentially) asking questions of the data that humans might not have thought to ask.

The capabilities of partnering brain imaging with artificial intelligence are already impressive. For instance, the technique can reconstruct, from noninvasively detected changes in localized brain blood flow, what letters of the alphabet a subject is currently observing, and can even make remarkably good guesses as to the key features of static images someone is viewing.[14] And, beyond that,

12. THE BRAIN INITIATIVE, https://braininitiative.nih.gov [https://perma.cc/BBV4-7JJM].

13. For information, resources, and the online bibliography of all known neurolaw works, see *Law and Neuroscience*, MACARTHUR FOUND. RSCH. NETWORK, www.lawneuro.org [https://perma.cc/U3BG-3XQB]. For an overview of some neurolaw experiments, including those that partner fMRI with machine-learning algorithms, see Jones & Wagner, supra note 2.

14. *See, e.g.*, Frank Tong & Michael S. Pratte, *Decoding Patterns of Human Brain Activity*, 63 ANN. REV. PSYCH. 483 (2012).

some labs have been using the techniques to reconstruct rudimentary video images a subject is watching.[15] I have little doubt that this is all just the beginning for the brain imaging, artificial intelligence partnership.

C. Theoretical Advances from Further Integrating Relevant Fields

Universities have divided reality up into pieces, thought to map onto departmental fields. Often, this has proved useful. Often, it has erected large gothic edifices that directly impair progress in understanding what's what, and why.

Although there have been major calls for increasing interdisciplinarity in order to tackle some of the most difficult or complex problems in the world, and although there has been some progress, most people are still trained, promoted, grant-funded, and teaching within the limited boundaries of one field, which drags an anchor on advancement.

In the context of something as complicated as understanding the brain, there have been some major interdisciplinary initiatives holding great promise. For instance, Clara Wu and Joe Tsai have helped Stanford and Yale—in their respective Wu Tsai Institutes[16]—to make massive moves into this interdisciplinary space on human cognition. The Institutes will pull together the fields of psychology, biology, computation, and a wide variety of others.

On the path toward an even larger transdisciplinary integration of brain sciences, I particularly hope the next ten years will begin bringing together two fields of behavioral biology—neuroscience and evolutionary biology—that at present operate almost entirely independently. Fundamentally, there are different but entirely

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15. *See, e.g.*, Shinji Nishimoto et al., *Reconstructing Visual Experiences from Brain Activity Evoked by Natural Movies*, 21 CURRENT BIOLOGY 1641 (2011). Beyond that, at least one lab has been working to decode words from thoughts. *See* Chris Bourn, *The Billionaire, the Pig and the Future of Neuroscience*, SLOW JOURNALISM (Aug. 28, 2020), https://www.slow-journalism.com/from-the-archive/the-billionaire-the-pig-and-the-future-of-neuroscience [https://perma.cc/5A8K-6GF7] (reporting on 2015 work to train an algorithm to predict intended words from neural signals associated with thinking that word).

16. *Wu Tsai Neurosciences Institute*, STAN. UNIV., https://neuroscience.stanford.edu/ [https://perma.cc/5KNE-2FTY]; *Wu Tsai Institute*, YALE UNIV., https://wti.yale.edu/ [https://perma.cc/Y62H-TDH2].

complementary kinds of causes in biology—generally known by their (admittedly clunky) terms as proximate and ultimate causes.[17]

Neuroscience today is almost entirely an exploration of proximate causes—that is, the investigation of *how* something happens, such as how it gets started, how it unfolds, what affects its happening, and what are the consequences.

Evolutionary biology, on the other hand, explores ultimate causes—that is, *why* evolutionary processes have left us with the brains we have, doing what they do, and non-randomly associating various suites of environmental inputs with behavioral outputs that tended, on average, to be adaptive in ancestral environments for those organisms that bore such predispositions.

But just as all species-typical body forms and behaviors must be understood to have both proximate and ultimate biological causes—both always simultaneously relevant—so should all brain form and function be similarly understood.[18] There are pathways of knowledge we simply are not exploring when neuroscience and evolutionary biology—focusing on how and why respectively—remain as siloed and isolated from one another as they, in most respects, are today.

II. NEUROLAW

Turning next to the projected intersections of neuroscience and law, over the coming ten years, there are many more potential topics here than I could cover in a reasonable space.[19] So I will only highlight a few.

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17. For discussion of these central concepts, see John Alcock & Paul Sherman, *The Utility of the Proximate-Ultimate Dichotomy in Ethology*, 96 ETHOLOGY 58 (1994); Ernst Mayr, *Cause and Effect in Biology*, 134 SCIENCE 1501 (1961).

18. For an exploration of how understanding both proximate and ultimate causation can be useful to law, see Owen D. Jones & Timothy H. Goldsmith, *Law and Behavioral Biology*, 105 COLUM. L. REV. 405, 454-57 (2005).

19. Judge Morris Hoffman has made his own useful set of predictions. *See* Morris B. Hoffman, *Nine Neurolaw Predictions*, 21 NEW CRIM. L. REV. 212 (2018). And I likewise recommend Stephen J. Morse, *Neuroethics: Neurolaw*, OXFORD HANDBOOKS ONLINE (2017), https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199935314.001.0001/oxfordhb-9780199935314-e-45 [https://perma.cc/6KEH-49CD], for a variety of thoughts about the future of the field. For questions raised about the future implications of neurolaw, topically, see JONES ET AL., *supra* note 3.

Here I'll give examples of potential Law and Neuroscience developments of five sorts. Across five Sections I'll discuss detecting things law cares about, individualizing developmental stages and brain states, evidence-based legal reforms, legal decision-making, and brain-brain interfaces.

A. Detecting Things Law Cares About

I think the next ten years will reveal major progress in the ability of neuroscientific technologies and techniques to detect things that law cares about. Here are four brief examples.

1. Detecting Brain Injuries

We have come a long way from the days when brain injuries were most indicated, and most reliably, by fractured skulls or penetrated brain cases. We now know, and can often demonstrate, that the brain can be seriously injured—for instance by major blows, by repetitive minor blows, or by severe experiential traumas—even when the skull remains intact.[20]

I expect some neuroscientific advances over the next ten years will increasingly aid the legal system in understanding how to investigate, demonstrate, quantify, and anticipate projected recoveries (if any) from, and implications of, various injuries to a brain's *function*, beyond similar insights into injuries to a brain's *structure* (from which, in part, functional deficits are often deduced and investigated). In suitable circumstances, these could be relevant to the domains of torts, disability benefits, contracts, and criminal law, as well as estate law, among others.

2. Detecting, Validating, and Measuring Pain

In his majority opinion, in *Grammer v. Kohlhaas Tank & Equipment Co.*, Judge Sutin wrote, "[n]o one can measure another's pain and suffering; only the person suffering knows how much he or she is suffering."[21]

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20. *See* JONES ET AL., *supra* note 3, at 347-96.
21. 604 P.2d 823, 833 (N.M. Ct. App. 1979).

As a consequence, legal battles over the existence and amount of pain remain, so far, inevitable—precisely because there historically has been so little objective and reliable evidence on which to make a factual finding. As Professor Hank Greely has noted:

> Hundreds of thousands of legal proceedings each year in the United States turn on the existence and extent of someone's (usually a plaintiff's or claimant's) pain. Sometimes those are personal injury cases, in which plaintiffs seek damages for their "pain and suffering" for the past, present, and predictably future in the aftermath of accidents. Most of them are actually disability cases, brought under federal or state disability schemes, or against private disability insurers. Although the technical question in those cases is not pain per se, it is quite often a question as to whether the claimants' pains are so great as to prevent them from working.[22]

Against this background, there has been some really interesting work in the area of pain detection over the last ten years.[23] As you

22. Henry T. Greely, *Neuroscience, Mindreading, and the Courts: The Example of Pain*, 18 J. HEALTH CARE L. & POL'Y 171, 178 (2015) (footnotes omitted). As Professor Amanda Pustilnik has noted, the challenge of dealing with pain, legally, is compounded by the frequent conflation of chronic and acute pain. *See* Amanda C. Pustilnik, *Legal Evidence of Subjective States: A Brain-Based Model of Chronic Pain Increases Accuracy and Fairness in Law*, 25 HARV. REV. PSYCHIATRY 279, 282-83 (2017). And, further, the law has made a bit of a mess in drawing distinctions, as when enforcing insurance policies that are drafted this way, between "bodily" injuries and "mental" injuries—as if mental injuries exist someplace other than the brain, and the brain exists in some non-"bodily" location. Or when drawing the distinction explicitly, such as in RESTATEMENT (THIRD) OF TORTS: LIABILITY FOR PHYSICAL AND EMOTIONAL HARM § 4 cmt. b (Am. L. Inst. 2005), which argues for maintaining the distinction because there should be "more restrictive rules for recovery for emotional harm ... [given that] the existence and severity of emotional harm is usually dependent upon the report of the person suffering it or symptoms that are capable of manipulation or multiple explanations."

For discussion of how such dualism is—while legally maintainable as a fiction—untenable as a matter of neuroscience, see Francis X. Shen, *Sentencing Enhancement and the Crime Victim's Brain*, 46 LOY. U. CHI. L.J. 405, 418-21 (2014); Dov Fox & Alex Stein, *Dualism and Doctrine*, 90 IND. L.J. 975, 978 (2015).

23. *See, e.g.*, Maite M. van der Miesen et al., *Neuroimaging-Based Biomarkers for Pain: State of the Field and Current Directions*, 4 PAIN REPS. 751 (2019); Sean Mackey et al., *Neuroimaging-Based Pain Biomarkers: Definitions, Clinical and Research Applications, and Evaluation Frameworks to Achieve Personalized Pain Medicine*, 4 PAIN REPS. 762 (2019); Karen D. Davis, *Introduction to a Special Issue on Innovations and Controversies in Brain Imaging of Pain: Methods and Interpretations*, 4 PAIN REPS. 771 (2019); Karen D. Davis et al., *Brain Imaging Tests for Chronic Pain: Medical, Legal and Ethical Issues and Recommendations*, 13 NATURE REVS. NEUROLOGY 624 (2017); Joyce T. Da Silva & David A.

may imagine, the existence and amount of pain is very difficult to investigate.[24] But I have been impressed with some of the work.

It may come to pass that over the next ten years we will be able to distinguish, with some reasonable accuracy and reliability, between people in pain and people not in pain. We might also, although this is even more speculative, have developed some gross or relative measures of how much pain those in pain are in.

That could have a transformative effect on how some tort and disability claims unfold. And I would expect that such technologies and techniques would come quickly before courts on evidentiary motions, the results of which may bring some of this evidence, in some contexts, to be weighed in the balance during various judicial and administrative decisions.

3. Detecting Additional Biomarkers Relevant to Assessments of Future Recidivism

Parole determinations often hinge on necessarily imperfect predictions about future dangerousness and risks of recidivism. Anything that improves the predictive power of such actuarial decisions warrants close consideration. And one potential development over the next ten years will likely be some important additions

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Seminowicz, *Neuroimaging of Pain in Animal Models: A Review of Recent Literature*, 4 PAIN REPS. 732 (2019); Irene Tracey & Anthony Dickenson, *SnapShot: Pain Perception*, 148 CELL 1308 (2012); Naomi I. Eisenberger, *The Pain of Social Disconnection: Examining the Shared Neural Underpinnings of Physical and Social Pain*, 13 NATURE REVS. NEUROSCIENCE 421 (2012); R. Peyron et al., *Functional Imaging of Brain Responses to Pain: A Review and Meta-Analysis*, 30 NEUROPHYSIOLOGIC CLINIQUE 263 (2000); Justin E. Brown et al., *Towards a Physiology-Based Measure of Pain: Patterns of Human Brain Activity Distinguish Painful from Non-Painful Thermal Stimulation*, 6 PLOS ONE 24124 (2011); Massieh Moayedi et al., *Pain Neuroimaging in Humans: A Primer for Beginners and Non-Imagers,* 19 J. PAIN 961 (2018).

For legal perspectives on pain detection, see Pustilnik, *supra* note 22; A.C. Pustilnik, *Imaging Brains, Changing Minds: How Pain Neuroimaging Can Inform the Law*, 66 ALA. L. REV. 1099 (2015); Amanda C. Pustilnik, *Pain as Fact and Heuristic: How Pain Neuroimaging Illuminates Moral Dimensions of Law*, 97 CORNELL L. REV. 801 (2012); Adam Kolber, *Pain Detection and the Privacy of Subjective Experience*, 33 AM. J.L. & MED. 433 (2007); Adam J. Kolber, *The Experiential Future of the Law*, 60 EMORY L.J. 585 (2011); Brady Somers, *Neuroimaging Evidence: A Solution to the Problem of Proving Pain and Suffering?*, 39 SEATTLE U. L. REV. 1391 (2016).

24. Even defining pain has proved challenging. *See generally* NAT'L INST. OF NEUROLOGICAL DISORDERS & STROKE, PAIN: HOPE THROUGH RESEARCH (2020).

to the existing literature on brain biomarkers correlating positively or negatively with probabilities of rearrest (as a very conservative measure of recidivism, since it's very difficult to know with reasonable precision the rate of recidivism by individuals who are never apprehended).

One interesting study by neuroscientists Eyal Aharoni, Kent Kiehl, and colleagues, first scanned ninety-six prisoner subjects in a mobile MRI, within prison boundaries, during an impulse control decision-making task, and then followed the rearrest records of those subjects.[25] Fifty-three percent had been rearrested for a crime within four years of release.[26]

When the neuroscientists explored the relationships between brain features and function on one hand, and the probabilities of subsequent rearrests on the other, they found something interesting about the relative amounts of activity in the anterior cingulate of subject brains (a region already believed in the neuroscience community to be involved in inhibiting undesirable behavior). Specifically, "[t]he odds that an offender with relatively low anterior cingulate activity would be rearrested were approximately double that of an offender with high activity in this region, holding constant other observed risk factors."[27]

In a subsequent paper, the authors provided additional analysis of their data, comparing the ratio of the true positive fraction to the false positive fraction, when comparing predictive models that either did or did not include predictions based on activity in the anterior cingulate. They found that the relative true positive classification rate was approximately seven percentage points higher when the model includes the anterior cingulate brain activity data than when it does not.[28]

True, this is only an incremental gain. On the other hand, no one expects brain data—or any other single actuarial element—to predict recidivism perfectly. Progress in predictive ability of actuarial tools depends on adding and refining factors that move decision

25. *See* Eyal Aharoni et al., *Neuroprediction of Future Rearrest*, 110 PROC. NAT'L ACAD. SCIS. 6223 (2013).

26. *Id.* at 6227.

27. *Id.* at 6223.

28. Eyal Aharoni et al., *Predictive Accuracy in the Neuroprediction of Rearrest*, 9 SOC. NEUROSCIENCE 332, 335 (2014).

makers in the direction of making more accurate predictors, under conditions of uncertainty, than they would make in the absence of considering such factors. So the suggestion of these papers, that brain data can help increase the accuracy of a predictive model, provides not only a fascinating proof of concept, but also (assuming replication studies) a positive development of the kind we are likely to see more of in the next decade.

To be clear, no one is suggesting that the relative amount of anterior cingulate activity should drive any parole decision, by itself. Nor is anyone suggesting that, prior to offending, people with low activity there should be treated differently, in the eyes of the law, than other people who have not offended. The question is simply whether or not brain data, when added to the mix of factors already considered during parole decisions, improve predictive accuracy. And the existing studies suggest brain data can do that, warranting further investigation.

4. Detecting Memories

Memories obviously play key roles in many legal actions, both civil and criminal. And although psychologists have been able to learn a tremendous amount about memories generally, the complementary neuroscientific investigation of memory is relatively young. Still, there have been some remarkable advances, which I expect will usher in many more, over the next ten years.

For example, although it is not yet widely known and appreciated, the pairing of fMRI brain data with machine learning algorithms has enabled researchers to detect—on the basis of brain data alone—the existence of autobiographical memories.[29] Imagine anyone predicting such a thing, say, twenty or more years ago. It would have seemed entirely far-fetched.

In one project of the Research Network, for instance, a Working Group on Deception and Recognition, led by Stanford's Anthony Wagner, hung small automatically operating cameras around the necks of students, during their daily activities.[30] This provided the

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29. *See* Jesse Rissman et al., *Decoding fMRI Signatures of Real-World Autobiographical Memory Retrieval*, 28 J. COGNITIVE NEUROSCIENCE 604 (2016).

30. *Id.*

lab with a reasonably reliable record of what visual environments each student had encountered.

In somewhat simplified summary, the lab then scanned the brains of subjects who were seeing randomly sequenced photographs that were always either: (a) from their own cameras (and lives); or (b) from the cameras of other students. The machine learning algorithm was then provided with all the brain data from the own-camera stimuli and all the brain data from the others'-cameras stimuli and then allowed to discover (if you will) on its own what patterns in the two different sets of brain data reliably distinguished them.

The next step, of course, was to show the algorithm brain data from that same subject, who now saw a different combination of photographs (from her own life and others'), *without informing the algorithm which brain data were from subjects seeing which kind of stimuli*. Researchers then tasked the algorithm to make predictions about whether the brain data collected during observation of a given photo indicated that the subject was seeing a photo from her own camera, or from someone else's.

To the surprise of all of us in the Research Network, as well as in the lab, the algorithm was able, under some laboratory conditions, to make that prediction with greater than 90 percent accuracy.

As a proof of concept, this is plainly remarkable, as that kind of accuracy level is rarely achieved. Equally remarkable is that roughly that same level of accuracy was achieved when the algorithm was trained up on one person's brain data, and then asked to make predictions about whether *someone else's* brain data indicated that they were seeing images from their own autobiographical lives, or not.[31]

This suggests there is something broadly generalizable about how the human brain functions when it recognizes a visual stimulus as matching an existing memory. This kind of work provides us with an increasingly deep window into how human memory works. And although it's at this point impossible to predict accurately how such work will intersect with the law's perennial efforts to assess the

31. *Id.* at 615 ("The neural signatures of these distinct memory states were sufficiently consistent across participants to yield comparable accuracy levels even when classifier models were trained and tested on data from different participants.").

quality, accuracy, suggestibility, and change of memories, it seems clear that there will be important points of contact.

B. Individualizing Developmental Stages and Brain States

I think the next ten years will reveal increasing abilities to individualize the relative brain development and brain states of subjects, compared to the reference groups of which that individual is a part.

True, there is already considerable variability among individuals in brain shapes and functions. Also true, some very important conceptual work has been done, by a Research Network Working Group on Inferences from Group Neuroscientific Data, led by now-Chancellor David Faigman of the University of California, Hastings.[32]

But by suggesting that there will be increasing emphasis on individuals, I mean to highlight that although most neuroscientific advances have resulted in findings that generalize to the groups for which subjects were chosen as representatives, the ability to say something potentially meaningful about how an *individual* compares to the *average* of the groups will increase, as the datasets, technologies, and techniques grow and improve. And this will have potential implications for those domains and activities of the legal system that are more immediately concerned with individuals, as in a criminal trial, than they are with large social groups, as when legal policies are being developed.

Here are three examples.

1. Brains of Adolescents and Young Adults

A great deal of work in neuroscience has focused on assessing how the brain changes as a person ages, with particular attention to the years just fore and aft of legal majority.[33] This makes sense when

32. *See, e.g.*, DAVID L. FAIGMAN ET AL, G2I KNOWLEDGE BRIEF (2016); David L. Faigman et al., *Group to Individual (G2i) Inference in Scientific Expert Testimony*, 81 U. CHI. L. REV. 417 (2014); David L. Faigman et al., *Gatekeeping Science: Using the Structure of Scientific Research to Distinguish Between Admissibility and Weight in Expert Testimony*, 110 NW. U. L. REV. 859 (2016).

33. *See, e.g.*, Kaitlyn Breiner et al., *Combined Effects of Peer Presence, Social Cues, and Rewards on Cognitive Control in Adolescents*, 60 DEVELOPMENTAL PSYCHOBIOLOGY 292 (2018); Grace Icenogle et al., *Adolescents' Cognitive Capacity Reaches Adult Levels Prior to Their*

one is considering legislative policies or judicial doctrines that might best apply to entire groups of people, such as minors generally.

One context in which this could play out is that neuroscientific findings might prompt us, on an ongoing basis, to consider whether there are better places to draw age-related lines, given our existing values that underlie our existing lines, many of which, as is well known, turn a juvenile into an adult on her eighteenth birthday. For instance, there is growing evidence that the human brain doesn't really finish its maturation process until people have reached their twenties.[34] Now if we're fully satisfied that age eighteen works for the purposes of law, there's of course no need to make a change, because facts don't drive values, and law juggles more vectors of values than just biological accuracy alone (if at all). Yet, to the extent the age eighteen threshold reflects in part an implicit assumption that the brain has finished developing by then, we might, in light of neuroscience, choose to reevaluate the wisdom of basing policy on that assumption.

Relatedly, findings from neuroscience might prompt us to consider whether there are more lines to be drawn for different purposes. For instance, a Research Network Working Group on Adolescent Development, led by Yale neuroscientist BJ Casey, studied young adults between the ages of eighteen and twenty-one. That team found that under some circumstances (particularly those involving emotional contexts and observation by peers), young adult brains and behavior more closely resemble the brains and behavior of juveniles, while under other circumstances young adult brains

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Psychological Maturity: Evidence for a "Maturity Gap" in a Multinational, Cross-Sectional Sample, 43 LAW & HUM. BEHAV. 69 (2019); Briana S. Last et al., *Childhood Socioeconomic Status and Executive Function in Childhood and Beyond*, 13 PLOS ONE 1 (2018); B.J. Casey & Kristina Caudle, *The Teenage Brain: Self Control*, 22 CURRENT DIRECTIONS PSYCH. SCI. 82 (2013); B.J. Casey et al., *Adolescence: What Do Transmission, Transition, and Translation Have to Do with It?*, 67 NEURON REV. 749 (2010); CHARLES A. NELSON ET AL., NEUROSCIENCE OF COGNITIVE DEVELOPMENT: THE ROLE OF EXPERIENCE AND THE DEVELOPING BRAIN (2006); Laurence Steinberg, *Cognitive and Affective Development in Adolescence*, 9 TRENDS COGNITIVE SCI. 69 (2005); Jason Chein et al., *Peers Increase Adolescent Risk Taking by Enhancing Activity in the Brain's Reward Circuitry*, 14 DEVELOPMENTAL SCI. 1 (2011); Michael Dreyfuss et al., *Teens Impulsively React Rather than Retreat from Threat*, 36 DEVELOPMENTAL NEUROSCIENCE 220 (2014); Katherine E. Powers et al., *Consequences for Peers Differentially Bias Computations About Risk Across Development*, 147 J. EXPERIMENTAL PSYCH.: GEN. 671 (2018).

34. *See, e.g.*, Nitin Gogtay et al., *Dynamic Mapping of Human Cortical Development During Childhood Through Early Adulthood*, 101 PROC. NAT'L ACAD. SCIS. 8174 (2004).

and behavior more closely resemble the brains and behavior of older adults.[35] Some argue that this young adulthood reflects a distinct developmental stage of human development, and that—perhaps—the law should consider tailoring some justice policies specifically when young offenders are members of this group.[36]

The point is not that the law should or shouldn't make any change in light of neuroscience. The point is that—depending entirely on what we're trying to accomplish and why we've chosen the locations for existing lines we've drawn—we might wish to consider new information when thinking about whether there are improvements that might be made, so as to more effectively pursue our already-existing values.

Which brings me, again, to the question of the next ten years. So far, we've been talking about how the legal system might draw lines between, and handle, members of different age groups. Yet the direction and pace of advances in neuroscience suggest that, in the next ten years, we may see an increasingly fine-grained ability to say that a single individual before the court has a brain that developmentally is either less physically mature, or alternatively more physically mature, than is the brain of the average person of his or her age.

The implications are not immediately obvious. If the person in question were, say, a young adult with a brain significantly less developed than others of his or her age, to what extent might society weigh this in favor of treating that individual, legally, like a juvenile? Alternatively, if the person were a juvenile, with a brain significantly more developed than others of his or her age, to what extent might society weigh this in favor of treating that individual, legally, like an adult?

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35. Alexandra O. Cohen et al., *When Is an Adolescent an Adult? Assessing Cognitive Control in Emotional and Nonemotional Contexts*, 27 PSYCH. SCI. 549 (2016); Marc D. Rudolph et al., *At Risk of Being Risky: The Relationship Between "Brain Age" Under Emotional States and Risk Preference*, 24 DEVELOPMENTAL COGNITIVE NEUROSCIENCE 93 (2017). For discussion, see Elizabeth S. Scott et al., *Young Adulthood as a Transitional Legal Category: Science, Social Change, and Justice Policy*, 85 FORDHAM L. REV. 641 (2016); Elizabeth Scott et al., *Brain Development, Social Context, and Justice Policy*, 57 WASH. U. J.L. & POL'Y 13 (2018); Elizabeth Scott et al., *Juvenile Sentencing Reform in a Constitutional Framework*, 88 TEMP. L. REV. 675 (2016).

36. *See, e.g.*, B.J. Casey et al., HOW SHOULD JUSTICE POLICY TREAT YOUNG OFFENDERS? (2017). For policy level discussion, see Alexandra O. Cohen et al., *When Does a Juvenile Become an Adult? Implications for Law and Policy*, 88 TEMP. L. REV. 769 (2016).

Note that I'm not taking a position on this. And that's not because I have one and am hiding it. It's instead because I think a decision on what the implications should or should not be of being in, say, the fifth percentile for the brain development of one's age cohort, warrants a very careful weighing of a wide swath of important values, the net results of which are not easily predicted in advance.

So we may choose, either legislatively (for example, by prohibiting neuroscientific evidence of this individualized kind) or judicially (for example, by allowing such evidence to reach the fact-finder, in the absence of legislation prohibiting it), to have a legal approach that reflects either a blanket treatment according to membership within an age group (which can be thresholded by bright lines) or that instead reflects a narrowly tailored set of factors to be considered, according to which legal treatment could vary. Either way, this strikes me as an arena that will be fraught with good intentions that can cut in opposite directions, which recommends deploying our best and most carefully considered discourse.

2. Brains in Decline

Of course, the young in society are bookended by the old. And so we'll likely see, in the next decade, similar developments and issues with respect to old age and dementia (at any age).[37]

We'll likely be seeing data that provide more functional indicators and additional structural biomarkers of cognitive decline and cognitive ability. And some of these will be relevant to legal determinations (particularly as maximum ages and average ages in society increase) for deciding such things as capacity and competence of individuals before the court.[38] And the same issues with respect to legal treatments of groups and legal treatments of individuals will inhere here, as with adolescents and young adults.

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37. For recent overviews, see generally THE AGING BRAIN: FUNCTIONAL ADAPTATION ACROSS ADULTHOOD (Gregory R. Samanez-Larkin ed., 2019); Gregory R. Samanez-Larkin & Brian Knutson, *Decision Making in the Ageing Brain: Changes in Affective and Motivational Circuits*, 16 NATURE REVS. NEUROSCIENCE 278 (2015).

38. *See, e.g.*, Betsy J. Grey, *Aging in the 21st Century: Using Neuroscience to Assess Competency in Guardianships*, 2018 WIS. L. REV. 735. For an examination of the potential relevance of neuroscience to judicial age and competence, see Francis X. Shen, *Aging Judges*, 81 OHIO ST. L.J. 235 (2020).

3. Brains in Drug Addicts

Similarly, I expect we'll see continuing progress in understanding how addictive drugs affect brains.[39] This may lead to an increasingly nuanced taxonomy, informed by neuroscience, that correlates different drugs with different group-based prospects for successful rehabilitation. And, again, we will probably see advances in the individualized assessment of how addiction is affecting the brains of particular addicts. And this, combined with other factors in an individual's circumstances, might yield improved actuarial estimates for the rehabilitation of individuals who have run afoul of the legal system—and, ideally, improved ability to make treatments available to addicts before they wind up in the criminal justice system.

There has also been some interesting work using transcranial, noninvasive, magnetic pulses to loosen the grip of various illegal drugs on the brain.[40] Assuming that work continues to show promise, we can imagine some serious discussions over the next decade, in light of our collective values and cost/benefit analyses, about whether such techniques can and should be made a condition of a probation or parole, for example.

C. Evidence-Based Legal Reform

Another context in which there may well be significant contributions over the next decade involves the accumulation of neuroscientific evidence that could inform potential reform. The examples given in the last Section are also examples of this context as well. But, more specifically, I am in this Section considering the extent to which discoveries from neuroscience may either buttress or

39. For perspectives on the effects of addiction on the brain, see Nora D. Volkow et al., *Addiction Circuitry in the Human Brain*, 52 ANN. REV. PHARMACOLOGY & TOXICOLOGY 321 (2012); Nora D. Volkow et al., *Neurobiologic Advances from the Brain Disease Model of Addiction*, 374 NEW ENG. J. MED. 363 (2016); CARLTON K. ERICKSON, THE SCIENCE OF ADDICTION: FROM NEUROBIOLOGY TO TREATMENT (2007); P. Read Montague, *The Freedom to Choose and Drug Addiction*, *in* 4 MORAL PSYCHOLOGY: FREE WILL AND MORAL RESPONSIBILITY 279 (Walter Sinnott-Armstrong ed., 2014); NAT'L INST. ON DRUG ABUSE, DRUGS, BRAINS, AND BEHAVIOR: THE SCIENCE OF ADDICTION (2014); Antonio Verdejo-Garcia et al., *A Roadmap for Integrating Neuroscience into Addiction Treatment: A Consensus of the Neuroscience Interest Group of the International Society of Addiction Medicine*, 10 FRONTIERS PSYCHIATRY, Dec. 2019, at 1.

40. Meredith Wadman, *Zapping Cocaine Addiction*, 357 SCIENCE 960 (2017).

challenge longstanding legal assumptions—many of which are, implicitly, about how people's brains work.

Here are three examples.

1. Assumptions About Solitary Confinement

Consider that the law implicitly assumes that solitary confinement does not affirmatively and significantly damage the brain. If it did result in nontrivial damage, that might run afoul of the U.S. Constitution's prohibition, in the Eighth Amendment, against cruel and unusual punishment.

Does it damage the brain? I don't know. But I suspect that there is some long-lasting damage.[41]

I was once given a tour of a maximum security prison by the state's Secretary of Corrections (to consider the prospect of a neuroscience study of effects of incarceration). Along the way, we encountered a man who had been in solitary confinement for fourteen years. One of the guards indicated that the man was so starved for interaction that he would, for hours, sit with his back to the door and his arm elevated so that his fingertips could protrude ever so slightly through openings in a small metal screen, hoping that one of the guards would simply touch a fingertip. They often did.

I would love to see a study that could shed light on the effects of solitary confinement on the brain. Whether there are or are not adverse effects, shouldn't we as a society want to know if neuroscience provides one of the tools for learning the facts?

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41. For discussion of some of the emerging work in this domain, see Huda Akil, *The Brain in Isolation: A Neuroscientist's Perspective on Solitary Confinement*, *in* SOLITARY CONFINEMENT: EFFECTS, PRACTICES, AND PATHWAYS TOWARD REFORM 199 (Jules Lobel & Peter Scharff Smith eds., 2020); Jules Lobel & Huda Akil, *Law & Neuroscience: The Case of Solitary Confinement*, 147 DAEDALUS 61 (2018); Arielle R. Baskin-Sommers & Karelle Fonteneau, *Correctional Change Through Neuroscience*, 85 FORDHAM L. REV. 423 (2016); Dana G. Smith, *Neuroscientists Make a Case Against Solitary Confinement*, SCI. AM. (Nov. 9, 2018), https://www.scientificamerican.com/article/neuroscientists-make-a-case-against-solitary-confinement/ [https://perma.cc/92FZ-346N]; Moheb Costandi, *Using Neuroscience Evidence to Argue Against Solitary Confinement*, DANA FOUND. (Jan. 3, 2019), https://dana.org/article/using-neuroscience-evidence-to-argue-against-solitary-confinement/ [https://perma.cc/HZ6M-EXEQ]; Kayt Sukel, *Understanding the Effects of Solitary Confinement on the Brain*, BRAINFACTS.ORG (Mar. 21, 2019), https://www.brainfacts.org/neuroscience-in-society/law-economics-and-ethics/2019/understanding-the-effects-of-solitary-confinement-on-the-brain-032119 [https://perma.cc/8NV7-N2GJ].

2. Assumptions Underlying Evidentiary Rules

If there's one place the legal system has a lot of implicit reliance on neurological assumptions, it's in the evidentiary rules that are designed to prevent the jury from hearing certain kinds of evidence. And that's because the rules are designed to prevent fact-finders from receiving evidence (into their brains) that could taint their decision-making process (in their brains).

For example, Federal Rule of Evidence 803(1) creates a "present sense impression" exception to the general rule against admitting hearsay into evidence. It is based (essentially) on the assumption that people just aren't capable of lying quickly. But is that neurological assumption true?

At least one neuroscientist, Christopher Sundby (who is also a lawyer), has investigated that experimentally, using a technique known as electroencephalography (more commonly "EEG") to monitor brain activity during efforts to lie quickly.[42] The data, in brief, suggest that people may engage a different cognitive mechanism when lying in the moment versus after a delay, something revealed by changes in working memory load. On one hand, this finding comports with the assumptions underlying the present sense impression exception to rules against hearsay evidence, because it suggests that a third-party observer may be able to detect "tells" of a contemporaneous lie (for instance, a delayed response occasioned by increased working memory load), while a skilled cross-examination might be better for detecting a more fully prepared lie. On the other hand, the data also suggest that the transition from a contemporaneous lie to a prepared one can take place far faster than the present sense impression rule assumes (less than three seconds).

That proof-of-concept investigation suggests we could usefully see similar investigations of other evidentiary rule assumptions, across the coming decade.

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42. Christopher Sundby, Does Lying Require More or Less Working Memory and What Does it Mean for the Legal System? (May 8, 2020) (Ph.D. dissertation, Vanderbilt University) (on file with Vanderbilt University Institutional Repository), https://ir.vanderbilt.edu/handle/1803/16026 [https://perma.cc/86EA-J7M6].

3. Assumptions About Criminal Mental States

As is well known, criminal convictions typically require both a bad act and that the act have been performed by someone in one of several culpable mental states. As a reminder, the widely influential Model Penal Code (MPC) divides culpable mental states into four types: purposeful, knowing, reckless, and negligent.[43] Punishment amounts, for the very same prohibited action, vary significantly according to the mental state the defendant is judged to have been in. In Colorado, for instance, a person who kills someone recklessly can be sentenced to something as low as probation without prison time, while a person who killed someone the identical way, but knowingly, can be sentenced to as many as forty-eight years in prison.[44]

Putting someone into a mental state box has enormous consequences. But—and leaving aside for now the evidence suggesting that jurors are not nearly as reliable in doing this as we'd like[45]—do the boxes really exist as the MPC assumes? That is: To what extent do these four abstract creations, in a neatly labeled taxonomy, map onto psychological reality?

If the MPC mental states are distinct, then they must reflect different brain states. So, in order to prevent injustice, don't we

43. *See* MODEL PENAL CODE § 2.02 (AM. L. INST., Proposed Official Draft 1962). For discussion of the MPC's influence, see Paul H. Robinson & Jane A. Grall, *Element Analysis in Defining Criminal Liability: The Model Penal Code and Beyond*, 35 STAN. L. REV. 681, 691-92 (1983).

44. COLO. REV. STAT. § 18-3-103(1)-(3)(a) (2010) defines second degree murder, without any heat of passion mitigator, as a Class 2 felony. Class 2 felonies ordinarily carry a non-mandatory presumptive sentence of eight to twenty-four years. *Id.* § 18-1.3-401(1)(a)(V)(A). Murder is often considered to be a crime of violence, however, a determination that has the effects of (1) increasing the range to sixteen to forty-eight years; and (2) making a prison sentence mandatory. *Id.* § 18-1.3-406(1)(a), (2)(a) (pertaining to murders involving deadly weapons or to crimes causing serious bodily harm or death). A reckless murder is classified as manslaughter, however, and carries a nonmandatory sentence of two to six years. *Id.* § 18-3-104(1)(A). The statute defines manslaughter as a Class 4 felony. *Id.* § 18-3-104(2). Class 4 felonies carry a nonmandatory presumptive sentence of between two and six years. *Id.* § 18-1.3-401(1)(a)(V)(A.1). Colorado does not define manslaughter as a crime of violence. *Id.* § 18-1.3-406.

45. *See* Francis X. Shen et al., *Sorting Guilty Minds*, 86 N.Y.U. L. REV. 1306 (2011); Matthew R. Ginther et al., Essay, *Decoding Guilty Minds: How Jurors Attribute Knowledge and Guilt*, 71 VAND. L. REV. 241 (2018); Matthew R. Ginther et al., *The Language of Mens Rea*, 67 VAND. L. REV. 1327 (2014).

need to know whether brain states vary the way the MPC assumes? The moral legitimacy of the MPC taxonomy depends on whether those mental states *actually correspond* to different brain states in the way the MPC categorization assumes. Otherwise, we are punishing people differently when there is no nonarbitrary basis for doing so.

Although the MPC is over fifty years old, the empirical basis of its categories had never been tested until recently (because neuroscientific technologies and techniques to test it only became available relatively recently).

A Research Network team, led by Gideon Yaffe, developed an fMRI-based brain-scanning task, coupled with a machine learning algorithm, to see if there were reliable differences in brain activation between subjects in a knowing state of mind and subjects in a reckless state of mind.[46] And the key finding is that, under some conditions, the algorithm was extremely reliable in identifying when our subjects were in a knowing frame of mind or a reckless one.

So these results provide the first empirical support for law drawing a line between knowing and reckless criminality, according to which different punishments will follow. Of course, finding differences between those two brain states doesn't mean we must automatically keep the distinction between knowing and reckless in the MPC. Nor would failure to find brain differences require abandonment of the distinction. Instead, this proof-of-concept experiment provides a concrete example of how neuroscientific methods can contribute information relevant to legal policy.[47] In this case, a test of an assumption underlying the policy.

How policymakers choose to weigh that information is a matter of law and politics, not science, as values, facts, costs, benefits, and fundamental principles get weighed in the balance. But our discovery may provide the first step in work, over the next decade and beyond, toward legally defined mental states that reflect actual and detectable psychological states, grounded in neural activity

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46. *See* Iris Vilares et al., *Predicting the Knowledge-Recklessness Distinction in the Human Brain*, 114 PROC. NAT'L ACAD. SCIS. 3222 (2017). For further discussion and exploration of the implications of this study, see Owen D. Jones et al., *Detecting Mens Rea in the Brain*, 169 U. PENN. L. REV. 1 (2020).

47. Not everyone agrees. *See, e.g.*, Andreas Kuersten & John D. Medaglia, *Neuroscience and the Model Penal Code's Mens Rea Categories*, 71 DUKE L.J. ONLINE 53 (2021).

within the brain. And this illustrates the way that neuroscientific investigations and evidence can inform, without dictating, intelligent and thoughtful legal reform.

I think there's also potential, in this vein, to use brain scanning to help learn about possible origins of other distinctions the law draws, such as the differences between tort harms and criminal harms, libel and slander, justification and excuse, and retribution and deterrence. Similarly, it may prove illuminating to learn more about how the brain makes legal judgments, distinct from moral ones. About what happens in the brain when someone is directed to forget (as when jurors are instructed to disregard what they have just heard). And about whether there are cross-cultural differences in brain activation when considering core harms versus noncore harms.[48]

D. Legal Decision-Making

We know that few things are more important to the just administration of the legal system than having jurors and judges who can make unbiased decisions about the cases before them. At the same time, we know that humans are notoriously prone to a wide variety of psychological biases.

Until relatively recently, we had no way of knowing—as but one important part of an inquiry into the nature of law-relevant decision-making—how human brains go about deciding whether someone is guilty of a crime, and—if so—how much that person should be punished. To investigate, a Research Network Working Group on Intent and Punishment that I headed explored the extent to which fMRI might illuminate the neural processes underlying these determinations. These findings could potentially provide valuable information for improving training interventions intended to help debias them.

Using fMRI brain scans, while subjects were tasked with making liability and punishment decisions (regarding offenders in hypothetical scenarios), that Working Group identified distinct brain activity that separately correlate with four key components of those

48. As to the distinction, see Paul H. Robinson et al., *The Origins of Shared Intuitions of Justice*, 60 VAND. L. REV. 1633, 1674-75 (2007).

decisions: (1) assessing harms, (2) discerning mental states in others, (3) integrating those two pieces of information, and (4) choosing punishment amounts.[49]

The ability to noninvasively discover which regions of the brain are active when, and how, during distinctly different components of legal decision-making suggests a proof of concept that could be usefully extended, in the coming years, to other legal decision-making inquiries. Ripe for study, for instance, is what effect—if any—legal training and experience has on brain activity during various kinds of legal decision-making. I'll add that our initial foray into this domain, comparing brain activity of active judges with matched controls lacking legal training discovered no significant difference—which is, to my mind, itself an interesting (non)discovery. How does legal education (like all forms of education) change the brain? Are there differences that correspond with age, sex, political leanings, or other variables? Are there differences in how brains are used in different kinds of decisions, such as a disputed contract interpretation, on one hand, and a rape trial, on the other? Is the brain activity associated with different outcomes sufficiently distinct that a machine learning algorithm could accurately classify the decisional outcome, based on brain data alone? How do different drugs, that judges and jurors might be taking, affect brain activation in key decision-making regions? How do brain-regions interact when considering mitigating factors on one hand, and aggravating factors, on the other?

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49. *See generally* Matthew Ginther et al., *Parsing the Behavioral and Brain Mechanisms of Third-Party Punishment*, 36 J. NEUROSCIENCE 9420 (2016). That work built upon studies by prior, and sometimes differing, configurations of these same co-authors. *See* Joshua W. Buckholtz et al., *The Neural Correlates of Third-Party Punishment*, 60 NEURON 930 (2008) (finding correlations between guilt and punishment decisions and activity in regions commonly associated with analytic, emotional, and theory-of-mind processes); Michael T. Treadway et al., *Corticolimbic Gating of Emotion-Driven Punishment*, 17 NATURE NEUROSCIENCE 1270 (2014) (finding that theory-of-mind circuitry may either gate or suppress affective neural responses, tempering the effect of emotion on punishment levels when, for instance, a perpetrator's culpability was very low while, at the same time, the harm he caused was very high); Joshua W. Buckholtz et al., *From Blame to Punishment: Disrupting Prefrontal Cortex Activity Reveals Norm Enforcement Mechanisms*, 87 NEURON 1369 (2015) (using repetitive transcranial magnetic stimulation (rTMS) to test the causal role of right dorsolateral prefrontal cortex and finding, as predicted, that compared to sham stimulation rTMS changed the amount that subjects punished protagonists in scenarios without altering how much they blamed those protagonists).

E. Brain-Brain Interfaces

I first saw video footage of a brain-robot interface in 2012, when I was part of a small working group invited to the Vatican by the Pontifical Academy of Sciences. The group's charge was to discuss neuroscience and the human person. And Professor John Donoghue, a leader in brain-machine interface research, showed an astounding video.[50] In it, a paraplegic woman with a brain implant and a wireless transmitter was able to control a robotic arm and hand with such precision that, using her mind alone, she could direct it to locate, grasp, and lift a cup of coffee, bring it to her mouth, tipping it gently so she could drink, and then returning it to its original position on a nearby table.[51]

In light of that experience, I predicted during the instant Symposium, in February of 2021, that within ten years we would see human brain-to-brain interfaces. Instead, it took negative 1.5 years. Because, as I recently learned, it had already happened.[52] A study published in mid-2019 demonstrated that three human subjects could collaborate on a computer task (similar to playing the object-rotating game *Tetris*) using only brain-to-brain interfaces, using a combination of EEG and transcranial magnetic stimulation.[53]

As remarkable as this is, it remains far too rudimentary to communicate complex thoughts clearly. Still—and although I do not subscribe to precisely the same level of enthusiasm that Elon Musk has evidenced recently, about the near future of high-capability brain implants[54]—it seems entirely reasonable to predict that the

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50. Owen D. Jones, *Seven Ways Neuroscience Aids Law*, *in* NEUROSCIENCES AND THE HUMAN PERSON: NEW PERSPECTIVES ON HUMAN ACTIVITIES 181 (Antonio M. Battro et al. eds., 2012).

51. This line of research is described in Donoghue, *supra* note 9.

52. This is, incidentally, a very reliable way of making accurate predictions.

53. Linxing Jiang et al., *BrainNet: A Multi-Person Brain-to-Brain Interface for Direct Collaboration Between Brains*, SCI. REPS., Apr. 16, 2019, at 1.

54. Jo Best, *Elon Musk's Brain-Computer Startup Is Getting Ready to Blow Your Mind*, ZDNET (Sept. 15, 2020), https://www.zdnet.com/article/elon-musks-brain-computer-startup-is-getting-ready-to-blow-your-mind/ [https://perma.cc/CT8J-RST2]. For a description of Neuralink, the company co-founded by Musk, see Nick Statt, *Elon Musk Launches Neuralink, a Venture to Merge the Human Brain with AI*, THE VERGE (Mar. 27, 2017, 4:10 PM), https://www.theverge.com/2017/3/27/15077864/elon-musk-neuralink-brain-computer-interface-ai-cyborgs [https://perma.cc/3XB4-7GZJ].

next decade will bring some (further) advances in brain-to-brain communications.

And what that inspires us to think about, in advance, is what legal implications would follow in the wake of increasingly sophisticated brain-to-brain communications. For instance, what would bad behavior look like in this context? Are there unwelcome forms—or content—of communications we want to discourage, with narrowly tailored innovations in tort law? What would constitute the elements of criminal assault in this context? Could there be successful fraud or misrepresentation claims, based on testimony about brain-to-brain content? Could someone accept an offer, brain-to-brain, thereby forming a legally enforceable contract? And when two people are engaged in brain-to-brain communications, could one of them manifest, without speaking a word, legal consent to sexual interactions?

CONCLUSION

A symposium on "Imagining the Future of Law and Neuroscience" provides a valuable exercise in thinking about what new discoveries, opportunities, and challenges are coming down the pike.

On one hand, I don't expect any neuroscientific advance will yield widespread upheaval in the justice system, or its thorough reimagining. On the other hand, I do expect that accelerating progress in neuroscientific technologies and techniques will continue to bring information to the legal table—which, after being evaluated for its reliability, relevance, and utility in light of legal standards and purposes—may aid, and sometimes challenge, some of the many important decisions that perpetually confront us.