The Journal of Appellate Practice and Process

Volume 1 | Issue 2 Article 4

1999

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Erica Beecher-Monas

Edgar Garcia-Rill

THE LAW AND THE BRAIN: JUDGING SCIENTIFIC EVIDENCE OF INTENT

Erica Beecher-Monas* and Edgar Garcia-Rill, Ph.D.**

INTRODUCTION

As evidentiary gatekeepers, judges must be ready to evaluate expert testimony about science and the brain. A wide variety of cases present issues of mental state, many doubtless with battling experts seeking to testify on these issues. This poses a dilemma for nonspecialist judges. How is a nonscientist to judge scientific evidence? How can a nonscientist decide if testimony about mental state meets the criteria of good science? This essay offers a general overview of the issue of evaluating scientific evidence and is aimed at exploring the issues involved, but not attempting easy answers. Of necessity, this requires thinking about how science works. It is also an introduction to the special case of mental capacity, which requires thinking about how the brain works.

Exercising discretion about expert testimony is a radically different task today than it used to be. In a series of three revolutionary cases, the Supreme Court transformed the jurisprudence of expert admissibility determinations, with results that are reverberating throughout the judicial system. The Supreme Court's revolutionary trio explains that judges are the gatekeepers of the testimony that is heard in their courtrooms, and that all expert testimony—including expert psychological testimony—must meet standards of scientific validity. Although mental health testimony is crucial to criminal jurisprudence as well as to a range of civil actions, the courts have been

* Assistant Professor of Law, University of Arkansas at Little Rock School of Law.
** Professor of Anatomy and Psychiatry, University of Arkansas for Medical Sciences.

permitting experts to testify to outmoded and unscientific notions without any scrutiny of the scientific validity of the testimony. Failure to engage in a validity analysis is an abuse of discretion.

The Supreme Court has said that there is no room for junk science in the courtroom, and that includes testimony about mental state. Expecting experts to demonstrate the scientific validity of their theories may challenge the justice system, but it is the least we should expect from a system that strives for rationality. The Supreme Court's transformative trio has the potential to finally dispatch outdated notions about mental state and to bring decisions of the legal system into synch with modern understandings of how the brain works.

In *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[1] the Supreme Court laid the groundwork for this transformation by requiring district court judges to evaluate the scientific validity and "fit" of expert testimony. In *General Electric Co. v. Joiner*,[2] the Court reiterated the *Daubert* standards, expounded on its notion of "fit," and explained that, while the standards for admissibility had changed, the traditional abuse of discretion standard of review had not. Finally, in *Kumho Tire v. Carmichael*,[3] the Court explained that not only do judges have to evaluate the validity of testimony regarding the traditional "hard" sciences, but they also must evaluate the validity of expert testimony based on what the lower courts call the "soft" sciences, such as engineering and psychology.[4]

Radical transformations are never painless, and this one has met with its share of resistance. Certainly, the task of evaluating expert testimony is a far more complex task after *Daubert* than it was before. Difficult as it may be, however, requiring judges to

1. 509 U.S. 579 (1993).

2. 522 U.S. 136 (1997).

3. 119 S. Ct. 1167 (1999).

4. *See id.* at 1175. For cases drawing this distinction between "hard" and "soft" sciences, see, e.g., *Jensen v. Eveleth Taconite Co.*, 130 F.3d 1287, 1297 (8th Cir. 1997) (noting that "[t]here is some question as to whether the *Daubert* analysis should be applied at all to 'soft' sciences such as psychology"); *United States v. DiDomenico*, 985 F.2d 1159, 1171 (2d Cir. 1993) (finding "soft" science expertise is less likely to overwhelm the common sense of the average juror than "hard science" expertise); and *United States v. Scholl*, 959 F. Supp. 1189, 1191 (D. Ariz. 1997) (noting that although *Daubert's* criteria "are more easily applied to the rigid sciences . . . they have also been applied to the soft sciences such as psychology and psychiatry").

evaluate the validity of proffered evidence is a vast improvement over merely counting scientific noses to determine admissibility.[5]

Nor is it a task that is beyond the judiciary. Not only did *Daubert* itself give the courts some flexible guidelines, but the Federal Judicial Center published the *Reference Manual on Scientific Evidence* in 1994, scores of articles have been written offering guidance on different aspects of the determination,[6] and a number of exemplary judges have been applying *Daubert* routinely and well.

Understanding the probabilistic thinking used by scientists is the key to sound scientific validity determinations. Appellate judges who must decide whether trial judges met their gatekeeping duties need to know how to reason about science. They also need to know that mental state is not an either-or-proposition, but a probabilistic statement about the likelihood of being in control of one's faculties at any given time. This essay will focus on expert psychological testimony and address two fundamental issues with which a reviewing court will need to grapple in order to determine whether expert testimony about mental state meets the criteria of good science. The first of these is, how does science work? And the second is, how does the brain work? This essay hopes to contribute to the understanding of both.

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5. The general acceptance standard, applied by the district court in *Daubert*, involved determining whether the expert's conclusions had achieved consensus in the expert's field. *See* Daubert v. Merrell Dow Pharmaceuticals, Inc., 727 F. Supp. 570, 571 (S.D. Cal. 1989), *aff'd*, 951 F. 2d 1128 (9th Cir. 1991), *rev'd*, 509 U.S. 579 (1993). For nearly seventy years before *Daubert*, the general acceptance standard of *Frye v. United States*, 293 F. 1013 (D.C. Cir. 1923) was the predominant standard for determining the admissibility of expert evidence. *See* Edward W. Kirsch, *Daubert v. Merrell Dow Pharmaceuticals, Inc.: Active Judicial Scrutiny of Scientific Evidence*, 50 FOOD & DRUG L. J. 213, 213 (1995).

6. *See, e.g.*, Erica Beecher-Monas, *A Ray of Light for Judges Blinded by Science: Triers of Science and Intellectual Due Process*, ____ GEORGIA L. REV. ____ (1999); Margaret A. Berger, *Procedural Paradigms for Applying the Daubert Test*, 78 MINN. L. REV. 1345 (1994); David E. Bernstein, *Junk Science in the United States and the Commonwealth*, 21 YALE J. INT'L L. 123 (1996); Troyen A. Brennan, *Environmental Torts*, 46 VAND. L. REV. 1, 21-42 (1993); Paul C. Gianelli, *"Junk Science": The Criminal Cases*, 84 J. CRIM. L. & CRIMINOLOGY 105 (1993); Jonathan J. Koehler, *Error and Exaggeration in the Presentation of DNA Evidence at Trial*, 34 JURIMETRICS J. 21 (1993); Michael J. Saks, *Implications of the Daubert Test for Forensic Identification Science*, 1 SHEPARD'S EXPERT & SCI. EVIDENCE Q. 427 (1997).

I. THE SUPREME COURT'S TRANSFORMATIVE TRIO

A. The Required Analysis

In the first of its three cases on expert testimony, *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[7] the Supreme Court emphasized the gatekeeping responsibilities of federal trial judges. The federal trial judge faced with a proffer of scientific testimony must first determine whether the expert's testimony is "scientific knowledge" that will assist the factfinder to determine a fact in issue.[8] To qualify as scientific knowledge, the Supreme Court held, "an inference or assertion must be derived by the scientific method."[9] The further issue of scientific relevance, or "fit," concerns whether otherwise valid testimony will actually assist the factfinder.[10]

The Court's explanation of scientific method was that scientific knowledge "implies a grounding in the methods and procedures of science."[11] Four "general observations" guide the inquiry.[12] They are testability, peer review and publication, error

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7. 509 U.S. 579 (1993). *Daubert* involved birth defect claims relating to the anti-nausea drug, Bendectin. *Id.* Plaintiffs had proffered expert causation testimony, which the trial and appellate courts ruled inadmissible. *See* Daubert v. Merrill Dow Pharmaceuticals, Inc., 727 F. Supp. 570, 571 (S.D. Cal. 1989), *aff'd*, 951 F.2d 1128 (9th Cir. 1991), *rev'd*, 509 U.S. 579 (1993). The Supreme Court reversed, categorically dispatching the general acceptance test used by the lower courts in their determinations, finding it to be a "standard absent from and incompatible with the Federal Rules of Evidence." *Daubert*, 509 U.S. at 590. Instead, the Court ruled, Federal Rule of Evidence 702 requires a court to examine proffered expert testimony to determine "whether the reasoning or methodology underlying the testimony is scientifically valid," and "whether that reasoning or methodology properly can be applied to the facts in issue." *Id.* On remand, Judge Kozinski once more found the expert testimony inadmissible. *Daubert*, 43 F.3d 1311 (9th Cir. 1995). One of the Supreme Court's most vocal critics, Judge Kozinski complained that "though we are largely untrained in science and certainly no match for any of the witnesses whose testimony we are reviewing, it is our responsibility to determine whether those experts' proposed testimony amounts to 'scientific knowledge,' constitutes 'good science,' and was 'derived by scientific method.'" *Id.* at 1316. This essay attempts to aid judges in meeting that responsibility by shedding light on how science works in the context of what we know about the workings of the brain.

8. *See Daubert*, 509 U.S. at 590.

9. *See id.* at 589.

10. *See id.* at 591.

11. *Id.* at 590.

12. *See id.* at 594 (characterizing the inquiry as a "flexible one").

rate, and general acceptance. These "flexible guidelines"[13] incorporate not only the Supreme Court's notion of the scientific method, but also its assessment of the importance to scientists of feedback from their peers. In setting out its standards for evaluating scientific validity, the Court relied heavily on the teachings of Sir Karl Popper, an eminent philosopher of science.[14] The goal of the *Daubert* inquiry, as the Court later explained in *Kumho Tire*, was to evaluate expert testimony by the standards experts themselves use to critique each other's work.[15]

Although the Court intended to focus the trial courts on the validity of the expert's techniques and methodology and away from the expert's conclusions,[16] that does not mean that the trial judge could ignore the expert's conclusions.[17] Rather, the trial court must examine the expert's methodology and techniques for consistency with the expert's conclusions and with the facts of the case at hand.[18] Conclusions and methodology, the Court pointed out in *Joiner v. General Electric Co.*, are not entirely distinct from one another, and there must be a valid connection between them.[19]

The Supreme Court has emphasized that the required analysis is not limited to the confines of traditional laboratory science. In *Kumho Tire Co. v. Carmichael*,[20] the Court explained

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13. *See id.*

14. *See id.* at 593 (citing Popper).

15. *See* Kumho Tire Co. v. Carmichael, 119 S. Ct. 1167 (1999).

16. Initially, the Supreme Court in *Daubert* recognized that the relevance of expert testimony depends upon whether the proffered testimony will resolve issues presented in the legal dispute before the court. *See Daubert*, 509 U.S. at 591. The role of the court, noted the majority, is to resolve factual disputes, some of which may involve contested scientific evidence. *See id.* The key question here is whether the proposed testimony is based on data that "fits," or is validly connected to, the facts of the case. *See id.*

17. *See* General Electric Co. v. Joiner, 522 U.S. 136, 143 (1997).

18. *See id.* This, the Court explained, is the issue of "fit." *See id.*

19. *See id.*

20. 119 S. Ct. 1167 (1999). *Kumho Tire* was a products liability action brought against a tire manufacturer and tire distributor by a plaintiff injured when a tire on the car he was driving blew out and the car overturned. *Id.* at 1167. The proffered expert was a tire failure analyst who proposed to testify that a defect in the tire's design or manufacture caused the blowout. *Id.* The trial court granted the defense motion to exclude on the basis of Federal Rule of Evidence 702. *Id.* After reconsidering the matter, the trial court agreed with the plaintiffs that *Daubert* should be applied flexibly, but still found the expert's testimony unreliable. *Id.* at 1173. The Eleventh Circuit reversed, reviewing de novo, and found that

that the basic gatekeeping obligation applies not only to "scientific" testimony, but to all expert testimony.[21] Technical or other specialized knowledge also falls within the purview of Federal Rule of Evidence 702 along with scientific knowledge; and it must similarly meet a standard of evidentiary reliability.[22] The Court explained that the language of rule 702 makes no distinction between "scientific" knowledge and "technical" or "other specialized knowledge."[23] Moreover, the rationale underlying *Daubert*'s gatekeeping requirement is that the expert's opinion have a reliable basis.[24] Further, it would be difficult, if not impossible, to draw a distinction between scientific, technical, or other specialized knowledge.[25] Thus, *Daubert*'s general principles apply to all expert testimony.[26]

Emphasizing the flexible nature of the *Daubert* inquiry, the Supreme Court explained that not all four factors necessarily apply even in the traditional laboratory sciences.[27] For example, publication and peer review may be absent if other scientists were previously uninterested in the topic.[28] That does not make the witness's testimony unreliable. And just because the general acceptance factor can be met does not necessarily mean that the testimony is reliable, where, for example, the entire discipline lacks reliability.[29] Nor is there any logical reason to exempt

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the tire expert's testimony lay outside the scope of *Daubert*. Carmichael v. Samyang Tire, Inc., 131 F.3d 1433, 1435 (1997). The Supreme Court reversed. *See* Kumho Tire Co. v. Carmichael, 119 S. Ct. 1171 (1999).

21. *Kumho Tire*, 119 S. Ct. at 1174.

22. *Id.*

23. *Id.*

24. *Id.*

25. *Id.*

26. *Id.*

27. In the years following *Daubert*, a number of courts were circumventing their gatekeeping responsibilities by drawing a distinction between "hard" sciences, such as physics and medical research, and "soft" sciences such as psychology, engineering, and most criminal identification evidence (such as handwriting analysis). *See* Erica Beecher-Monas, *Blinded by Science: How Judges Avoid the Science in Scientific Evidence*, 71 TEMPLE L. REV. 55, 63-67 (1998). Some courts, on the other hand, drew no such distinction, and applied *Daubert* principles to all expert testimony. *See, e.g.*, United States v. Posado, 57 F.3d 428, 432 (5th Cir. 1995) (holding that the general requirements of *Daubert* apply to all specialized knowledge). This split in the circuits was the impetus behind granting certiorari in the *Kumho Tire* case. *See Kumho Tire*, 119 S. Ct. at 1173.

28. *Kumho Tire*, 119 S. Ct. at 1173.

29. *Id.* at 1175 (giving the examples of astrology and necromancy).

technical or experience-based testimony from questions about its error rate and methodology.[30] Understanding the methodology, requiring the existence and maintenance of standards controlling the technique's operation, and examining how often a given procedure yields mistaken results, are crucial to evaluating an expert's conclusions. Unless standards are maintained and observed for a given technique, the absence of quality control will make a reliability assessment impossible. The objective of the *Daubert* analysis is to ensure the reliability and relevance of expert testimony and to be certain that an expert employs the same professional standards of intellectual rigor in the courtroom as is expected in the practice of the relevant field.[31] In sum, the Court concluded, "a trial court should consider the specific factors identified in *Daubert* where they are reasonable measures of the reliability of expert testimony."[32]

B. The Standard of Review

The Supreme Court granted certiorari in *Joiner* to resolve a raging debate among the circuits over the proper standard of review. The appellate court had rejected the trial court's scientific validity analysis of proffered cancer causation testimony, reversing the district court's exclusion.[33] While the appellate court claimed to be using an abuse of discretion standard in reviewing the district court's admissibility determination, it applied the standard in a "particularly stringent" manner because of the Federal Rules' preference for admissibility.[34] The Supreme Court reversed, explaining that the traditional abuse of discretion standard of review applied even to scientific validity determinations. The Supreme Court characterized the appellate court's review as "overly stringent" and as failing to "give the trial court the deference that is the hallmark of abuse of discretion review."[35]

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30. *Id.*
31. *Id.*
32. *Id.*
33. General Electric Co. v. Joiner, 522 U.S. 136, 140 (1997).
34. Joiner v. General Electric Co., 78 F.3d 524, 529 (11th Cir. 1996).
35. *See Joiner*, 522 U.S. at 143.

Traditionally, the trial court is given wide latitude on evidentiary determinations and appellate courts will review only for abuse of discretion.[36] *Daubert* mandated a validity determination, but was silent on the standard of review. Most jurisdictions applied the abuse of discretion standard to the *Daubert* analysis.[37] At least one court, however, had applied a heightened abuse standard, revisiting the trial court's decision, though giving some deference to its determination.[38] Some courts used a two-step standard of review, in which the reviewing court undertook de novo review to determine whether the trial court properly followed the *Daubert* framework, followed by review of its admissibility determination for abuse of discretion.[39]

In addition, in *Kumho Tire,* the Court further explained the abuse of discretion standard of review it had previously addressed in *Joiner.*[40] Emphasizing the need for "latitude in deciding how to test an expert's reliability," the Court explained that the abuse of discretion standard of review applies "as much to the trial court's decisions about how to determine reliability as to its ultimate conclusion."[41] Whether, and how, to apply *Daubert*'s specific factors is a question left to the discretion of the trial judge.[42]

Of course, this discretion must not be abused, and courts do not have discretion to ignore *Daubert* where it applies. Thus, the court abuses its discretion when it does not engage in a validity

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36. United States v. Sinclair, 74 F.3d 753, 757 (7th Cir. 1996).

37. *See, e.g.,* McCullock v. H.B. Fuller Co., 61 F.3d 1038, 1042 (2d Cir. 1995) ("manifestly erroneous" standard); Government of Virgin Islands v. Sanes, 57 F.3d 338, 341 (3d Cir. 1995); (abuse of discretion); Benedi v. MacNeil-P.P.C, Inc., 66 F.3d 1378, 1384 (4th Cir. 1995) ("Daubert clearly vests the district courts with discretion"); Pedraza v. Jones, 71 F.3d 194, 197 (5th Cir. 1995); Pestel v. Vermeer Mfg. Co., 64 F.3d 382, 384-85 (8th Cir. 1995); United States v. Hall, 93 F.3d 1337, 1342 (7th Cir. 1996). *See also* G. Michael Fenner, *The Daubert Handbook: The Case, Its Essential Dilemma, and Its Progeny,* 29 CREIGHTON L. REV. 939, 1028 (1996) ("almost all of the cases say the standard is broad or deferential, it is a clearly erroneous standard, it looks for manifest or clear abuse of discretion").

38. *See, e.g.,* In re Paoli R.R. Yard PCB Litig., 35 F.3d 717, 763-65 (3d Cir. 1994).

39. United States v. Hall, 93 F.3d 1337, 1342 (7th Cir. 1996). *But see* Hoult v. Hoult, 57 F.3d 1, 5 (1st Cir. 1995) (declining to "shackle the district court with a mandatory and explicit reliability analysis").

40. *See* Kumho Tire Co. v. Carmichael, 119 S. Ct. 1167, 1176 (1999).

41. *Id.*

42. *Id.*

analysis or when the validity analysis it does engage in is not soundly reasoned. For example, in *Kumho Tire*, the district court had made the required *Daubert* inquiry and, when it found that the testimony would not meet the criteria of good science, excluded the testimony.[43] However, because the expert testimony at issue was engineering testimony about tire failure, the Eleventh Circuit reversed, reviewing the district court's decision de novo, finding that "a *Daubert* analysis applies only where an expert relies on the application of scientific principles, rather than on skill- or experience-based observation."[44]

The Supreme Court disagreed. It held that rule 702 makes no relevant distinction between "scientific" knowledge and "technical" or "other specialized knowledge."[45] *Daubert* applies to expert testimony, period. Reviewing the district court's *Daubert* inquiry, the Supreme Court found its determination was a reasonable one.[46]

Accordingly, the required standard by which all expert testimony—whether it concerns laboratory science, engineering, or psychology—must be judged is its scientific validity and relevance. In order to decide whether expert testimony can meet this standard, judges must have some understanding of how science works to assess whether the testifying expert has met the scientific standards of intellectual rigor.[47] Without knowing what those standards are, rational validity decisions are unlikely.

To meet their gatekeeping duties, judges must have an overall grasp of the frame of reference used by scientists. Although an education in science is not required, understanding the context in which scientific argument evolves is crucial. Context is inseparable from argument, and understanding the paradigm shift that has occurred in modern science is imperative.

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43. *See id.* at 1173.

44. *Id.* (quotations omitted).

45. *Id.* at 1174.

46. *Id.* at 1177. The Supreme Court found no abuse of discretion in the district court's determination that the expert engineering testimony at issue "fell outside the range where experts might reasonably differ." *Id.*

47. *Id.*

II. HOW DOES SCIENCE WORK?

The *Daubert* Court's four flexible guidelines rely heavily for their genesis on the philosophy of science articulated by Sir Karl Popper. Thus, to understand how scientists see the world, and to judge whether their work meets the required standards of intellectual rigor, as well as to judge whether the Supreme Court got it right, it is helpful to understand something of Sir Karl's philosophy of science. Before we can address Popper's philosophy of science, however, we need to place his thoughts in historical context.

A. Newton's Laws and Determinism

For the last four hundred years, since the birth of modern physics, the attitude of scientists has been that everything could ultimately be explained in a scientific manner, that everything had a cause, and that, if somehow enough of the details could be known, everything could be explained. This is the essence of "reductionism." This idea arose from the description of Sir Isaac Newton's laws relating to force and acceleration, basically trajectories, which became the "laws of nature." These laws implied that, once the initial conditions are known, it is possible to calculate what would happen next and also what happened before. These laws were "deterministic" in that the past could dictate the future.[48] Everything was "fated" to happen. For example, factors A plus B plus C were equal to process X, and X, of course, was equal to factors A plus B plus C. That is, the equation ran in both directions across the equals sign. This introduced two conditions, causality and the reversibility of time. In terms of causality, the laws of motion boiled down to the collision of particles (which changed the direction or degree of motion of other particles). The Newtonian concept of cause stated that because the collision could be expressed in mathematical terms, so could the cause. The concept of cause was reduced to a mechanical event, which could then be expressed as a mathematical formula.[49]

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48. *See* ILYA PRIGOGINE, THE END OF CERTAINTY: TIME, CHAOS AND THE NEW LAWS OF NATURE 110 (1997).

49. For more on the reversibility of time, see Ilya Prigogine's book on the "arrow of

Science was therefore thought to be about causes, not chance. Classical science emphasized order and stability. These "laws" also implied that, given enough information, if enough factors were considered, every situation or state could be calculated with certainty. Newtonian determinism was the foundation for much scientific—and legal—thinking up until the early part of this century. But it is a limited vision, and can only take us so far. As a result, it has been replaced by a new understanding of how things work.

Now, in contrast, modern scientists see fluctuations, instability, multiple choices, and limited predictability at all levels of observation. Kant tried to make causation "*a priori* valid" through the principle of induction.[50] But every form of inductive logic leads to a "probable logic," and infinite regress. Then there is deductive reasoning, the type that produces firmly delineated causal chains. The first paradigm shift in modern science occurred when the uncertainty principle of Heisenberg and quantum physics led to the abandonment of certainty as a derivative of deductive reasoning.[51] Causality became "probable" rather than determined. Modern concepts of causation have been modified accordingly to allow for probability. If causality is a matter of theory, and if theories are modified over time, then causality is not a simple either/or proposition. The probability that one event caused another can be increased or decreased, depending on how well new evidence fits with the guiding theory, but it cannot be determined with absolute certainty.

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time." *See id.*

50. *See* PATRICIA SMITH CHURCHLAND, NEUROPHILOSOPHY 248 (1986). Inductive reasoning requires concluding a general rule from specific instances. Deductive reasoning uses a general theory to explain specific instances. For a more detailed discussion of inductive and deductive logic, see Beecher-Monas, *supra* note 6.

51. The "deterministic" Newtonian physics of trajectories was replaced by quantum physics, which described the world in terms of wave functions. For example, for a complex structure like the solar system, Newtonian mechanics implied that if sufficiently accurate measurements are made at one time, the future behavior of the system could be predicted fairly accurately. Using quantum mechanics to describe even a simple system like an atom with a single electron yields a very different result. Precise prediction of future behavior is impossible because the exact position of the electron cannot be determined accurately. Only predictions of the *probability* of various behaviors can be made. This is part of the first paradigm shift in modern science, from Newtonian physics to quantum mechanics.

B. Popper's Philosophy of Science

The new paradigm of probabilistic reasoning was instigated in no small part by the pathbreaking work of Sir Karl Popper, an eminent philosopher of science in this century. He helped engineer the shift away from induction towards deduction, provided one did not expect (scientific) deduction to consist of absolute certainty. He supported a deductive method of testing, emphasizing that a hypothesis can only be empirically tested (but can never be proven to be absolutely true), and can only be advanced *after* it has been tested. However, he also emphasized that there was no such thing as the "scientific method." He advanced the concept that there is no method of discovering a scientific theory, that there is no method of ascertaining the absolute truth of a scientific hypothesis (i.e., no method of verification), and that there is no method of ascertaining whether a hypothesis is probable, or probably true.[52] The closest he came to delineating a scientific method, as such, was to propose that, "rules of scientific procedure must be designed in such a way that they do not protect any statement in science against falsification."[53] It should be stressed here that Popper did not advocate that there is no way to conduct science. Rather, his position was that a "scientific method" that has "rules" that exclude alternate forms of inquiry should not be sanctioned. That is, Popper was reluctant to draft "rules" for scientific inquiry lest they hamper scientific evaluation.[54]

Popper realized that science is a creative endeavor—the search for new knowledge. He believed that scientific ideas should be formulated and tested. Such testing should involve tests of consistency within the theory, consistency against other theories and, of course, consistency with experimental data. Popper promoted the principle of falsifiability: that, whenever we propose a solution, we ought to try as hard as we can to overthrow our solution, rather than defend it. Theories, by surviving these tests, can come closer and closer to being true, but we only can be definite about the superiority of one theory

52. Karl R. Popper, *Realism and the Aim of Science*, in POSTSCRIPT TO THE LOGIC OF SCIENTIFIC DISCOVERY 6 (W.W. Bartley III ed. 1983).

53. KARL R. POPPER, LOGIC OF SCIENTIFIC DISCOVERY 40 (1959).

54. *Id.*

over another, not about its absolute truth. Science must continue to question and criticize all its theories, even those that happen to be true. We should prefer one theory over another as being "a closer approximation of the truth." That is, *the aim of science is to achieve better and better explanations.*

In addition, Popper believed in diversity in dialogue, which makes critical argument fruitful. That is, he did not believe in narrowing the scientist's focus of inquiry, but rather he believed in the interaction of various scientific disciplines. In fact, he was concerned that participation of the "scientific expert" would narrow the accessibility to the debate. He believed in rationalism, which basically means that to understand the world we learn by arguing with others, by testing ideas in the public forum. Thus, a background or education in science should not be a prerequisite to participating in the argument. The only things that the partners in an argument must share are the wish to know, and the readiness to learn from the other fellow by severely criticizing his views and hearing what he has to say in return. Popper posited that scientific theories are distinguished from myths merely in being criticizable, and in being open to modifications in the light of criticism. He believed that scientific knowledge is *not* an especially strict or certain or august kind of knowledge. Measured by the high standards of scientific criticism, "scientific knowledge" always remains probabilistic, although the probabilities are controlled by criticism and experiment. Probabilities cannot be induced (they can be "suggested") from observations.

C. Judging the Implications

On the one hand, considering Popper's insistence on the non-existence of the scientific method, it is puzzling that the Supreme Court insisted that scientific knowledge, in order to be valid, had to be derived from the scientific method. In *Daubert*, the Court implies that there is a set of rules—a concept that Popper thought would actually hamper evaluation.[55] On the other

55. The Supreme Court cited Popper for the proposition that testing hypotheses for falsifiability is the key to distinguishing science from non-science. *See* Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 593 (1993) ("The criterion of the scientific status of a theory is its falsifiability, or refutability, or testability") (citing KARL POPPER,

hand, the Court, by requiring judges to assess the validity of scientific evidence, is living up to some of the highest standards of Popperian philosophy. In practice, judges should insist on falsifiability (ideally, these experts should be ready to provide a list of weaknesses, implicit assumptions and untested conditions that apply to their position/conclusion), diversity (expert witnesses should be expected to provide explanations that the judges can understand, and to be able to satisfactorily refute or explain any concerns raised by the judge and/or other witnesses) and rationalism (we learn by arguing with others, even if we do not have a degree). All of these conform in general to the test of validity referred to as "testability" by the Supreme Court.[56]

In practice, however, many scientists strive to prove their theories correct (not incorrect), will defend them with evidence and/or with smoke, and will develop tunnel vision regarding the alternatives. While non-scientists believe that scientists follow the principle of falsifiability, in reality many do not. Moreover, it should be understood that science generally works not by deduction, but by metaphor. The heart works like a pump, the brain works like a computer (easy to understand but unrealistic metaphors). Most theories are based on sets of existing assumptions that follow some model, a metaphor for the process being studied. Science is generally done on models: architectural models, structural models, human models, animal models, cellular models. Each of these models differs to some degree with the "actual" process being studied, and all have intrinsic problems and hidden assumptions. However, these issues do not necessarily make them useless or unrealistic. There is no reason to suspect that results will not generalize to conditions not tested. For example, if an agent causes cancer in rats, it is likely that it will cause cancer in humans.[57] If we insist on having the human data, we may never obtain it (after all, it is highly unethical to carry out such studies on humans). Metaphors are very useful in validity determinations, but they must be good

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56. *See Daubert*, 509 U.S. at 593.

57. Although uncontroversial in science, this is an issue many courts misunderstand, thinking it a more controversial proposition than it really is. For further discussion, see Beecher-Monas, *supra* note 6.

metaphors. They must accommodate the evidence. That is why it is so important that judges understand how science works, so that they can adequately judge the validity of the metaphor.

The Supreme Court's reliance on peer review and publication/general consensus is also problematic. According to Popper, general consensus could be achieved, but criticism should always be welcome. This is particularly true in science, where many questions need to be reexamined in the light of new technology. Popper believed that once a hypothesis had proved its mettle, it should not be allowed to drop out without good reason. That is, the procedure of peer review and publication is one way to critique existing theories, which then are bolstered by passing the trial by fire, or are discredited in the literature.

In practice, things are less clear. Many accepted ideas later are proven erroneous, but only after proponents have defended them and even protected them by censoring attacks. Conversely, bodies of evidence are sometimes built around seemingly diametrically opposed scientific theories, as if the sheer weight of the piles of articles will prove one theory over another. It is amazing how, if you are around long enough, the answer closest to the truth lies somewhere in between the two theories, brought into the light of day by novel technology or rationale.

It is difficult to relate the Supreme Court's description of error rate to specific notions of Popper, except to say that the method used has to be consistent within itself, with other theories and with the data. However, it must be emphasized that, regardless of the error rate, there can only be an approximation to causality, an approximation to the truth, never a causal relationship. The probabilistic nature of science must be accepted, because expecting scientists to provide "hard and fast" answers, conclusive, absolutely certain definitions or findings is simply unrealistic. Being frustrated at a scientist's "buts," "ifs," "possibles," and "probables" is not constructive. What should be assessed is the consistency of the conclusion with the data, with competing theories, and with the proposed hypothesis.[58]

58. This can create an intellectual conundrum, especially when a method expresses its findings in a statistical format. Recent ideas suggest that the human brain is error-ridden (even irrational) when interpreting probabilities and percentages. However, when the same problems are presented in terms of frequencies, human reasoning appears statistically

Reductionism is losing ground because today's attitude is becoming more "realistic." That is, reductionism is being replaced with a vision that correlates more closely to what we now observe. New theories and ideas include: the concept of "non-equilibrium;"[59] concepts such as self-organization instead of determinism; the irreversibility of time instead of its reversibility; instability instead of stability; chaos instead of order. These are some examples of the theories that are replacing reductionist ideas. We now understand the world to be made of complex systems, rather than the simple, idealized situations of Newton.

The old Newtonian rules do not apply to complex systems because complex systems cannot be reduced to equations. Complex systems can only be considered in a statistical manner because they are probabilistic, not certain. The more factors added, the less likely it is that one can predict the ultimate position or state of an object. Complex systems have a "life of their own," they are "indeterminate." This is part of the second paradigm shift in modern science, the shift to complexity theory.

Complexity theory presents a new view of the world that describes what is going on around us and what has gone before. Granted, Newton, Einstein and a host of other physicists deserve inestimable credit for their insights in developing concepts that have essentially built modern society, but, indeterminism explains how instabilities and fluctuations can lead to evolutionary patterns at all levels, from cosmology to chemistry to biology, from the formation of the universe to the biology of the brain. The effects of billions of particles, of forces, of repetitive interactions, generate change, growth, movement, evolution and patterns. The simple repetitive process of one atom bumping into another, of those two bumping into many others, leads, not to random activity, but to coherence, to

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sound. *See* Gerd Gigerenzer, *Ecological Intelligence*, in THE EVOLUTION OF MIND 9-29 (Denise Dellardsa Cummins & Colin Allen eds. 1998).

59. Complexity theory attempts to provide an understanding of complex systems, from ant colonies to the human brain to economies to human cultures. Complex systems have many interacting parts, which can shape themselves into highly organized patterns and are constantly changing. That is, they never seem to settle down to a state of equilibrium and are thus in "non-equilibrium." For a general description of complexity theory, see M. MITCHELL WALDROP, COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS (1992).

concerted action, to organization, to a pattern. This is how the cosmos works, this is how evolution works, and probably how the brain works. This new science is the science of complexity, the kind of science needed to analyze and understand the real world. Complexity theory is the kind of science needed to analyze the brain, and to give us a new view of human beings.

The brain is the epitome of a complex system, with many interacting parts (nerve cells), which shape themselves into highly organized patterns of activity and are in constant "non-equilibrium." The normal function of the brain, therefore, has great variety and flexibility, making it difficult to determine the boundaries of its capacity. Given the complex nature of the brain, how can we address such concepts as understanding how to tell right from wrong, being responsible for our actions, and making moral choices?

III. WHAT WOULD POPPER SAY ABOUT MENTAL CAPACITY TESTIMONY?

Expert testimony about mental capacity is proffered under numerous circumstances, in both civil and criminal trials.[60] In criminal trials, especially, expert mental capacity testimony has become an important issue. It is often crucial to voluntariness of confessions,[61] competency to stand trial,[62] proving the substantive issue of criminal intent,[63] as an affirmative defense,[64]

60. *See* Ronald J. Rychlak & Joseph F. Rychlak, *Mental Health Experts on Trial: Free Will and Determinism in the Courtroom*, 100 W. VA. L. REV. 193, 194 (1997) ("Legal doctrines such as insanity, diminished capacity, and chemical dependency raise issues related to the mental health professions.").

61. *See, e.g.*, United States v. Hall, 974 F. Supp. 1198 (C.D. Ill. 1997) (subjecting expert testimony regarding coercion and false confessions to *Daubert* analysis, and finding it admissible).

62. Competency to stand trial generally requires that the defendant be able to understand the charges and assist in the defense. *See, e.g.*, United States v. Bruck, 152 F.3d 40 (1st Cir. 1998) (affirming district court's denial of a competency hearing); United States v. Chischilly, 30 F.3d 1144, 1150 (9th Cir. 1994) (finding defendant competent to stand trial despite uncontroverted testimony regarding defendant's selective memory, structural brain abnormalities and history of behavioral problems).

63. *See, e.g.*, Ratzlaf v. United States, 510 U.S. 135, 137 (1994) (mandating proof of knowing and intentional violation of a legal duty to meet statutory "willfulness" requirement); United States v. Skodnek, 896 F. Supp. 60, 62 (D. Mass. 1995) (finding expert testimony regarding mens rea subject to analysis under rule 702 and admissible).

64. *See* J. Thomas Sullivan, *Psychiatric Defenses in Arkansas Criminal Trials*, 48 ARK.

and at the sentencing stage.[65] The common law insanity defense—a variation of which is available in nearly all jurisdictions[66]—requires proof of the defendant's ability to distinguish right from wrong or to conform behavior to the requirements of law.[67]

In most criminal trials involving psychological testimony, the expert testimony will concern whether the defendant was suffering from a mental illness, such as schizophrenia or manic-depressive psychosis, or multiple personality disorder.[68] Occasionally, social framework evidence will be offered that describes typical psychological symptoms of a particular group of people, such as victims of child abuse.[69] Courts, however, widely ignore the issue of whether mental health testimony has any scientific validity.[70] Ordinarily, such testimony has crept into evidence without restriction.[71]

From a Popperian perspective, such deference to experts has little justification. Popper's philosophy rests on the triptych of falsifiability, diversity, and rationalism.[72] For mental capacity testimony, this means that testifying mental health experts must proffer data to support their hypotheses. An opinion as to the existence and implications of a hypothesized mental state—such as multiple personality disorder, for example—must be based on

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L. REV. 439, 440 (1995). Provocation, duress, and entrapment claims may also involve psychological testimony. *See* Christopher Slobogin, *Psychiatric Evidence in Criminal Trials: To Junk or Not to Junk?*, 40 WM. & MARY L. REV. 1, 7 (1998).

65. *See, e.g.*, United States v. Gigante, 996 F. Supp. 194 (E.D.N.Y. 1998) (expert testimony regarding competency to be sentenced met the *Daubert* standards).

66. In some version, the requirement that defendants know or appreciate the wrongfulness of their acts is the dominant form of excuse in all United States jurisdictions recognizing the insanity defense. *See* Sullivan, *supra* note 64, at 442.

67. This is the Model Penal Code approach, which provides that "[a] person is not responsible for criminal conduct if at the time of such conduct as a result of mental disease or defect he lacks substantial capacity either to appreciate the criminality of his conduct or to conform his conduct to the requirements of law." Model Penal Code § 4.01 (1962).

68. *See* Slobogin, *supra* note 64, at 7.

69. *See* Laurens Walker & John Monahan, *Social Frameworks: A New Use of Social Science in Law*, 73 VA. L. REV. 559, 560 (1987).

70. *See* Slobogin, *supra* note 64, at 27.

71. *See id.* at 1, 17 (observing that mental health experts testifying in insanity cases "have been able to say virtually anything they want in court, post-Frye, post-Rule 702, and post-Daubert . . . [with] the only significant limitation on such opinion . . . a prohibition on ultimate testimony concerning mental state, introduced in the federal system in the wake of the Hinkley trial in 1984, and even that limitation has had very little practical effect").

72. *See supra* 53-54 and accompanying text.

empirical data.[73] As a theory, the testimony must be open to challenge and modification; the idea must be formulated and tested, and all the available evidence must in some way be accounted for in the hypothesis, or at least the exceptions and/or alternatives should be noted and discussed.

The problem for courts is that brain science is an emerging field. Judges need to be prepared to continually rethink the issues of mental disorder in light of new data and new understandings of how complex systems—like the brain—interact. Courts, as conservative institutions, may resist having to continually revise their thinking about the evidence. It is certainly simpler to let experts testify as they always have. Moreover, accommodating the continual revisions in the way we understand brain function may revolutionize the criminal justice system. But accommodating new scientific understandings is what Popper, sound science, and *Daubert* demand. Subsequent scientific developments can discredit even the best factfinding previously available.[74] Mental state is such an important facet of our understanding of criminal responsibility that judges need to be open to the new ideas emerging in the field of brain science.

Much of what mental capacity experts proffer needs to be questioned. Conclusory subjective statements from an expert are unacceptable under *Daubert*. Expert testimony must be backed by hypotheses and data. A testifying expert must be able to explain the proffered hypothesis to a nonspecialist. The principle of diversity insists that scientific ideas have no professional boundaries. The aim of science is better explanation. Has the

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73. *See, e.g.*, Bowen v. State, 911 S.W.2d 555 (Ark. 1995) (opposing experts battled over whether the mental disorder known as dissociative disorder (or, more commonly, as multiple personality disorder) existed or not, but the judge apparently never required empirical support for either hypothesis).

74. A good example of this phenomenon is the way DNA evidence has revolutionized the criminal justice system. While such evidence has become a powerful prosecutorial tool in identifying the accused as perpetrator of the offense, it has also had a dramatic impact on the system by affording previously convicted defendants a means of attacking their convictions. By successfully arguing that the DNA evidence excludes the defendant, or by challenging the accuracy of the prosecution's DNA evidence, these defendants have utilized the emerging technology to challenge their convictions. In a recent case, for example, DNA evidence showed that a man convicted of rape in Georgia sixteen years earlier could not have been the perpetrator, resulting in the man's release from prison and the dropping of the rape charges by the prosecuting attorney. *See DNA Test Frees Convicted Rapist 16 Years Later*, ARK. DEM. GAZ., June 17, 1999, at 4A.

expert sought out pertinent data? How well does the hypothesis explain the available data? What is the error rate of the methodology? Has the testifying expert accounted for the opponent's conclusion? If the explanation is well supported and well reasoned, it meets the standards of scientific validity, even if it later proves to be wrong. The judge's gatekeeping function is not to decide the ultimate correctness of the theory, but only to determine whether it meets the criteria of sound science.

After *Kumho Tire*, it is clear that all expert testimony must be subjected to validity analysis before being admitted. Mental state testimony is traditionally proffered by experts and therefore logically falls within this purview.[75] Whether the product will improve as a result depends in large part on the application of the analysis by the judiciary.[76] Although the expert should be able to provide an understandable explanation about "normal" mental states as well as "abnormal" ones, in order to know what questions to ask it would be helpful for judges to have some idea of how scientists understand the brain to work.

A. How Does the Brain Work?

Two modern ideas are crucial to understanding the emerging field of brain science: probabilistic thinking and complexity theory. The probability that one event caused another changes depending on the available data. Therefore, causality is at best an approximation rather than a certainty. And the interactions of complex systems such as the brain are in constant non-equilibrium, giving its function great variety and flexibility, making the boundaries of its capacity hard to determine.

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75. *But see infra* notes 86-87 and accompanying text. The problem is that the Supreme Court's excursions into mental capacity testimony conflict with its *Daubert* rulings. *See infra* notes 88-96 and accompanying text.

76. *Cf.* David L. Faigman, *The Evidentiary Status of Social Science Under Daubert: Is it "Scientific," "Technical," or "Other Knowledge?"*, 1 PSYCHOL. PUB. POL'Y & L. 960, 971 (1997) (arguing that social science evidence ought to be subjected to *Daubert* analysis as a way of improving such testimony).

1. The Non-Linear Brain

Neuroscientists understand that the brain is non-linear at both the visible level and at the microscopic level. For example, the membrane potential of a single neuron changes in a non-linear fashion, as graded synaptic inputs all over its surface interact to create background noise, complexity arising even in individual brain cells. The membrane of the neuron has a threshold that represents a critical point at which action potentials fire away. The interactions between the membrane potential and the arriving graded synaptic inputs represent a complex system in non-equilibrium. The pattern of graded and action potentials generated by a population of neurons, in turn, may represent an even more complex system in non-equilibrium, leading to wavefronts of activity. Wavefronts of activity are self-organized entities, coherent forms of activity, ordered patterns emerging from elements in disequilibrium. This is known as coherence in brain activity, or mental order.[77]

Is there an appropriate metaphor for such activity? Every culture has had its characteristic model of how the brain works. Before the turn of the century, the brain was thought to work like the most powerful machine of the time, the steam engine. Then, the intricate anatomical description of nerve fibers visualized early in this century promoted the idea that the brain was like one of the newest complex machines, the telephone exchange. More recently, the brain has been equated to a computer, because it is seen as working in digital fashion (i.e., 0 or 1, on or off, linear). However, most of the activity of the brain is analog (i.e., like waveforms with an infinite number of values along peaks and valleys, nonlinear). Therefore, an appropriate metaphor appears to be that the brain works like an orchestra.

The various regions of the brain may be likened to the sections of an orchestra. Each of these areas has its characteristic types of nerve cells which are in contact with specific nerve cells in some or all of the other sections of the brain. It is the simultaneous and sequential activity of the different regions of the brain that gives rise to the music of our minds, that is, to thought and action. Nerve cells communicate with each other in

77. This metaphor is explored at length in an upcoming book by one of the authors. EDGAR GARCIA-RILL, BRAIN MUSIC (forthcoming).

the form of a Morse code very much like the individual notes being played by a specific instrument in the orchestra. The combined efforts of many nerve cells within a region that are active in unison in a repetitive manner generates a characteristic brain rhythm. This amalgamated Morse Code-like activity can be equated to the notes played together by each of the instruments in a section of the orchestra. When several brain regions are active simultaneously, they generate frequencies of activity in harmony with each other, very much in the way the different sections of the orchestra produce notes—frequencies of sound—to yield musical harmony, namely a melody. According to this metaphor, the function of the brain is to generate thought and movement, just as the function of the orchestra is to generate music.

2. Mental Disorder

Now that we view the brain as non-linear, probabilistic, at the transition between equilibrium and non-equilibrium, how are we to view mental disease?[78] Mental disorder is just that—disorder, or brain activity beyond the normal range of probabilities.[79] Normally, we have a wide range of options from

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78. Mental disease, for the present discussion, is limited to the specific disorders mentioned above, namely schizophrenia, anxiety disorder, and depression, but not to global conditions such as mental retardation or diffuse traumatic brain injury. Although mental retardation and diffuse traumatic brain injury may well fall within the scope of the "mental disease or defect" for legal purposes, the brain science relating to them is different and beyond the scope of this article.

79. This is hardly a revolutionary idea. First, it must be understood that there are large numbers of tests, rating scales and structured interviews used for psychological assessment. These tests are standardized methods of sampling behaviors in a reliable and valid way. *See, e.g.*, J.F. Clarkin & S. W. Hunt, *Psychological Assessment: Tests and Rating Scales*, in TEXTBOOK OF PSYCHIATRY 225 (J.A. Talbott et al. eds. 1988). Psychometrics is the name given to the application of statistical methods to the study of psychological phenomena. Perhaps the "bible" of psychometric studies of mental disorder is a classic textbook by H.J. Eynsenck, HANDBOOK OF ABNORMAL PSYCHOLOGY (1960). Since then, there has been a virtual explosion in the design and implementation of more and more specific psychometric tests. *See, e.g.*, I. GRANT & K. M. ADAMS, NEUROPSYCHOLOGICAL ASSESSMENT OF NEUROPSYCHIATRIC DISORDERS 654 (1996); G. GROTH-MARNAT, HANDBOOK OF PSYCHOLOGICAL ASSESSMENT 1026 (1997).

Second, psychometrics is used to describe the behavior of a population. Any population will show a distribution of scores on a test, which is known as a normal distribution or bell curve. We can describe a bell curve by two figures, the mean (the arithmetic average of the scores of the population) and the standard deviation (which

which we choose the more or less optimal path. Critical judgment can be said to be the capacity to narrow down the probabilities to a manageable number. Saddled with a mental disease, the range of probabilities increases. There are too many options, too many possible directions in which to go, and far too many of these options appear "logical." In the absence of critical judgment, it becomes easier to take a "flyer," or to follow a red herring of logic to its illogical—and in some cases criminal—fate.

To use a metaphor, imagine sanity as driving down the proper side of the road, The Road of Life. (Figure 1) Mental disease sometimes makes you disregard that center line, and even the side lines, so that you start occasionally driving on the oncoming lane and on the shoulders, perhaps even in the ditches on either side of the road, all at breakneck speed. "Normal" people may deviate slightly from the correct lane, but they will spend the majority of their driving time centered. In order to understand mental disorder, we need to know about normal mental states.

3. Three States

We know that the human brain has three states of activity. We are awake, asleep, or asleep and dreaming. The region of the brain that controls these states is deep in the brain, in the brainstem, in a part of the brain that has been conserved in evolution. This region is called the Reticular Activating System (RAS) and controls our sleep-wake rhythms by influencing the

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measures the spread of the scores of the population). The bell curve has a convex shape around the mean, and a concave shape at the two extremes, known as the tails of the distribution of scores.

Third, a particular individual's score can then be compared to the scores of the population, falling close to the mean or towards either tail of the bell curve. When an individual's score lies (usually) more than two standard deviations away from the mean, it is considered to be (statistically) significantly different from the mean of the population. This score can lie on the left or the right tail. That is, psychometric scales will reveal if an individual's score was outside the normal boundaries of behavior. These scales all measure continua within which the patients will fall, sometimes falling at one or the other extreme end of the distribution. Most patients, however, will show some measure of normalcy (close to the mean) on some tests, while other rating scales will clearly identify behavior outside the "normal" range of scores; i.e., mental disorder or behavior outside the normal range of probabilities.

wavefronts of activity that travel to higher centers. The RAS also controls our level of sensory arousal, or how we respond to the environment. It controls our basic "fight-or-flight" survival mechanism. When this region is disturbed or diseased, many aspects of our behavior are affected for the worse.[80]

Right now, we are awake (attested by complex, desynchronized wavefronts of activity induced by the RAS throughout the cortex, the convoluted outer shell of the brain, our most sophisticated brain region). A sudden, loud sound will instantly result in heightened, even more complex activity in the cortex. At the same time, our bodies will exhibit a startle response, and assume a "ready" position in order to respond. Respond in which way? Ready to fight or flee, to attack a prey or escape a predator. This response is exaggerated in several psychiatric and neurological disorders, and we will deal with those consequences below.

If we are tired or bored, we start drifting into drowsiness and ultimately into sleep. The RAS-influenced cortical wavefronts of activity become simpler, more synchronized, as we move into deeper and deeper restful sleep. However, after about ninety minutes of this, we suddenly shift into a complex pattern of desynchronized brain activity again.

The wavefronts of activity in the brain look like those in waking, but we are asleep. Because our brain waves look like those during waking, this state is known as "paradoxical" sleep. Because our eyes are moving frantically, this state is also known as "rapid eye movement" (REM) sleep. It is mostly during this state that we dream. During synchronized sleep, we toss and turn, but as we move into REM sleep, we stop moving; in fact, our muscles are paralyzed by our brains. The brain, specifically, the part of the RAS that controls REM sleep, does not want us to act out our dreams. Only our eyes are allowed to act them out, thus the eye movements.

One other important event occurs during REM sleep. When that part of the RAS controlling REM sleep is pounding away, blood flow to the frontal lobes decreases.[81] The frontal lobes are

80. Edgar Garcia-Rill, *Disorders of the Reticular Activating System*, 49 MEDICAL HYPOTHESES 379, 379-87 (1997).

81. *See* Pierre Maquet et al., *Functional Neuroanatomy of Human Rapid-Eye-Movement Sleep and Dreaming*, 383 NATURE 163, 163-66 (1996).

thought to be the prime regions responsible for critical judgment. Therefore, when we dream, critical judgment is lessened, probably by the reduced levels of oxygen in our frontal lobes. This is perhaps why we accept our dreams so readily, why we do not question that we are flying, why some accept that there is a highway through the living room, or why others listen unquestioningly to a disembodied voice telling them what to do. Every ninety minutes during sleep, we all suffer from a lack of critical judgment for variable periods of time, during which we usually dream from five to forty-five minutes. This particular state may be a key to understanding abnormal brain function, although it is obviously not the only key. Is it possible during waking for the brain to assume a state that is characterized by decreased blood flow to the frontal lobes, which thereby reduces critical judgment?

4. Hypofrontality

One of the key developments in the emerging field of brain science—and one that has the potential to revolutionize criminal jurisprudence—is the effect of hypofrontality on critical judgment. The reduction of blood flow to the frontal lobes is known as hypofrontality, that is, reduced function of the frontal lobes. Hypofrontality is present in a number of psychiatric and neurological disorders, but it occurs during waking.[82] For example, hypofrontality is present in schizophrenia, along with other symptoms that can be explained by disturbance in the RAS, such as hallucinations.[83]

Hallucinations have been proposed to represent REM intrusion into waking, that is, dreaming while awake.[84] If this is true, then schizophrenic individuals will experience a seemingly "real" event (because they know that they are awake), and accept it unquestioningly (because they are "hypofrontal" and have decreased critical judgment). Dream content could include

82. *See* Monte S. Buchsbaum et al., *Cerebral Glucography with Positron Tomography*, 39 ARCH. GEN. PSYCH. 251, 251-59 (1982).

83. *See* Daniel R. Weinberger et al., *Physiologic Dysfunction of Dorsolateral Prefrontal Cortex in Schizophrenia*, 43 ARCH. GEN. PSYCH. 114, 114-24 (1986).

84. *See* D.C. Dement, *Studies on the Effects of Rem Deprivation in Humans and in Animals*, 43 RES. PUBL. ASSOC. RES. NORM. MENT. DIS. 456, 456-63 (1967).

commands from a disembodied voice, which, after all, "must" be the voice of God or other authority directing some form of atonement or punishment on unsuspecting victims, including total strangers.[85]

What else can happen if this part of the RAS is overactive? We know that the startle response is exaggerated in schizophrenia. A sudden, loud sound may cause an exaggerated startle response, an excessive "fight-or-flight" reaction out of proportion to the stimulus. That individual could strike out violently (again, uncritically) at the perceived threat, or escape into a catatonic stupor, caused by too much "fight" or too much "flight."

We know that hypofrontality and overactivity in the part of the RAS controlling REM sleep is present to some extent and to varying degrees in such disorders as anxiety disorder (particularly in posttraumatic stress disorder), depression and manic-depression (now referred to as bipolar disorder).[86] In addition, persons with Parkinson's Disease and Huntington's Disease, and some with Attention Deficit Disorder appear to be hypofrontal.[87] A recent study using brain-imaging techniques found that, compared to non-violent individuals, psychopaths showed lowered blood flow in portions of the frontal lobes during processing of emotional words.[88] Another study, using a similar brain imaging technique, found reduced metabolism in the frontal lobes (and other areas of the brain) in murderers pleading guilty by reason of insanity compared to normal controls.[89]

Obviously, the fact that these disorders all share disturbances in the RAS to some extent, while differing widely in their symptomatology, means that other parts of the brain are also disturbed in various ways. These findings also suggest that hypofrontality is *not* specific to psychotic behavior or to violence, so that brain imaging techniques will not be able to

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85. *See* Garcia-Rill, *supra* note 80, at 381.

86. *See id.* at 382.

87. *See id.* at 384.

88. *See* Joanne Intrator et al., *A Brain Imaging (Single Photon Emission Computerized Tomography) Study of Semantic and Affective Processing in Psychopaths*, 42 BIOLOGICAL PSYCHIATRY 96-103 (1997).

89. *See* Adrian Raine et al., *Brain Abnormalities in Murderers Indicated by Positron Emission Tomography*, 42 BIOLOGICAL PSYCHIATRY 495-508 (1997).

differentiate between, for example, (a) a depressive patient; (b) a wheelchair-bound Parkinson's Disease patient; or (c) a psychopath. It should be noted that critical judgment may be influenced by factors other than hypofrontality, but we simply do not have enough information about them. While we do know that critical judgment is the province of the frontal lobes, we do not know if *all* critical judgment is exercised by the frontal lobes, adding uncertainty even in the light of so much knowledge about the brain.

5. The Road of Life

Are these unfortunate—mentally ill—individuals always hypofrontal? Obviously not, since their behavior much or some of the time appears to be within normal boundaries. Just as normal individuals are not always happy or sad, many of these individuals are not always functioning abnormally. As we go down the Road of Life, some of us (normal individuals) will stay more or less in the right lane, occasionally exceeding the speed limit, sometimes skirting the center line, sometimes even the side line. A psychotic individual, perhaps with sociopathic tendencies, will veer from the right lane into the left, oncoming lane when a car approaches in the opposite direction, all at breakneck speed, perhaps even doing so when the oncoming car is merely a hallucination. However, at some point in time, that individual will return to the right lane. (See Figure 1).

People with depression may lose so much critical judgment that the survival instinct is erased, that is, they are suicidal. These individuals may go from the right lane onto the ditch on the right, even for long periods of time during that depressive (hypofrontal) episode. The bipolar individual may be veering wildly from the right ditch then quickly to the left ditch. For example, bipolar mothers are often overwhelmed by the prospect of caring for their own children, that is, their disease is serious enough to erase the mothering instinct.

However, all of these individuals will, at some point or other, find themselves in the right lane. At such an instant in time, for example, in a courtroom, such individuals may act within normal boundaries and appear competent to stand trial. They will be able to identify the judge, the defense attorney, themselves, and understand the charge. However, that does not

mean that the manner in which the current criminal justice system treats such people makes sense in light of their condition. For example, will they be able to stay in the right lane throughout the trial to assist in their defense? Questionable. Were they on the wrong side of the road when the crime was committed? Highly likely. Will they find themselves on the wrong side of the road in the future? Highly likely, if they remain without treatment. Are they in full command of their faculties? Sometimes. Should they be punished for a "crime" they now know was wrong? Probably not; perhaps they should be treated. What if there is no effective treatment? How should the criminal justice system treat these individuals?

B. Mental Capacity in the Courts

So, how do the courts deal with issues related to abnormality in the most complex structure on the planet? How can we analyze a problem in a system we are just beginning to understand? The Supreme Court has required a *Daubert* analysis of all expert testimony.[90] Yet the testimony in two important Supreme Court cases involving mental capacity opinions that are still being followed today could not withstand a *Daubert* analysis. In the first of these opinions, *Moore v. Duckworth*,[91] the Supreme Court upheld the constitutionality of proving sanity by the testimony of lay witnesses.[92] That is the equivalent of

90. *See* Kumho Tire v. Carmichael, 119 S. Ct. 1167 (1999).

91. 443 U.S. 713 (1979).

92. *Id.* at 714 (rejecting the defendant's contention that there was insufficient evidence of sanity where the prosecution relied solely on lay witness testimony to prove sanity, the defense had presented expert testimony to the contrary, and the prosecution had proffered no expert rebuttal testimony). The Court found no constitutional infirmity since Indiana law permitted sanity to be proved by either expert or lay testimony. *Id.* at 715. The open question now is whether there is constitutional infirmity in convicting a defendant based on evidence that could not meet the criteria for admissibility. *See also* Davasher v. State, 823 S.W.2d 863, 866 (Ark. 1992), where a paranoid schizophrenic patient "tortured by religious delusions"—who had not been taking his medication—was convicted of killing his former girlfriend and her mother despite uncontroverted testimony by the state psychiatrist that the defendant lacked the capacity to appreciate the criminality of his conduct or to conform his conduct to the requirements of law. The court's rationale was that although the Arkansas criminal code permits a judge to acquit on the grounds of mental disease or defect, it does not require acquittal. *Id* at 871. Rather than focusing on the element of intent, which the prosecution must prove beyond a reasonable doubt, the Arkansas Supreme Court chose instead to focus on mental disease or defect which the

permitting lung cancer causation testimony by lay witnesses, a result that is clearly antagonistic to *Daubert*. Both lungs and brain are physical organs. Mental disease has a physical basis, even though we do not yet know exactly how it works. Diagnosis of mental disease, like that of physical disease, is the basis of specialized knowledge, and that is the province of experts.

Even more egregious than permitting lay witnesses to testify about disease is the Supreme Court's position on admissibility of future dangerousness testimony. In *Barefoot v. Estelle*,[93] the Supreme Court upheld mental capacity testimony about future dangerousness that flies in the face of scientific evidence. At issue was the constitutionality of permitting psychiatrists to testify about the defendant's future behavior, given that such predictions are wrong two out of three times. No one (including psychiatrists) can predict with any degree of reliability that an individual will commit other crimes in the future.[94] Moreover, the psychiatrists in question had never examined the defendant personally.[95]

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defense must prove by a preponderance of the evidence, a burden that the court found the defense had not met. *Id.* at 871. Although the court recognized the persuasiveness of the unrefuted expert testimony that the defendant was not legally responsible for his acts at the time of the offense, it nonetheless found that the jury was not bound to accept the expert testimony as conclusive. *Id.* Contrast this result with that in the civil case *Joiner*, where the Supreme Court held that no reasonable jury could find that the element of causation had been established by the admissible expert testimony. *See* General Electric Co. v. Joiner, 522 U.S. 136 (1997). If causation cannot be established by a preponderance absent admissible expert testimony, it is difficult to see how intent of a paranoid schizophrenic can be established beyond a reasonable doubt in the face of unrefuted testimony to the contrary. Even under the Arkansas court's rationale, moreover (that the defense had the burden of proving mental disease by a preponderance), its ruling that the defense had not met its burden is clearly wrong. The expert testimony on the issue was uncontroverted, so the jury had no other testimony on that issue to weigh. The reason experts are permitted to testify at all is that they can explain matters outside the jury's experience. While the jury is competent to decide among competing strands of evidence, it is not entitled to reach a decision contrary to the admissible expert testimony—at least in a civil case. *Cf. Joiner*, 522 U.S. at 141. *Daubert* requires a court to admit only reliable testimony. Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 590-91. Lay testimony on a subject of scientific knowledge is inadmissible in a civil court. *See* Kumho Tire v. Carmichael, 119 S. Ct. 1167 (1999). How then can it be admissible in a criminal case where the stakes are so much higher?

93. 463 U.S. 880 (1983).

94. Unfortunately, even in states that have established a *Daubert*-type admissibility standard, such as Texas, lay testimony may still be admissible to with respect to future dangerousness. *See, e.g.*, East v. State, 702 S.W.2d 606, 613 (Tex. Crim. App. 1985) (en

At the sentencing proceeding in *Barefoot*, two psychiatrists testified that the defendant "would probably commit future acts of violence and represent a continuing threat to society."[96] The Supreme Court upheld the admissibility of such testimony, remarking that disallowing it would be like "disinvent[ing] the wheel."[97] Because courts had traditionally admitted such testimony, the Court refused to overturn its precedent. However, as Justice Holmes pointed out nearly a century before, just because it has always been done this way is a poor reason to continue. That is especially true of issues relating to science, which is continually revising our understanding of how things work.

The Court acknowledged the American Psychiatric Association's opposition to future dangerousness testimony because of its extreme unreliability. Nonetheless, it found that because the Association did not claim that psychiatrists were *always* wrong with respect to future dangerousness predictions—only that they were wrong more often than not—it would not exclude such testimony. In light of *Daubert*'s emphasis on acceptable error rates, however, *Barefoot*'s decision is highly questionable.

It is also highly debatable from a Popperian viewpoint. We live in a world of probabilities, using a complex non-linear brain in a complex society. First, the normal boundaries of behavior are quite wide, especially because the brain functions at a transition between equilibrium and non-equilibrium. Second, the factors influencing behavior are complex and can only be considered probabilistic because there is never just one "cause." Any idea that we can control these factors leads at best to Orwellian fantasies. Third, the equilibrium of the brain can be radically altered by seemingly inconsequential stimuli.

Science is not a magic bullet; there is no method for unerring diagnosis, no recording of a brain wave that "proves"

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banc) (finding lay witness testimony on future dangerousness admissible). While it appears logical that admission of expert testimony that would not withstand a *Daubert* analysis has due process implications, the Court has not yet so held. A discussion of this issue is beyond the scope of this article.

95. *See id.* at 899.

96. *Id.* at 884.

97. *Id.* at 896.

this person is insane, or the like. We cannot (and will not be able to) predict what thought will enter someone's mind, for there are so many factors leading to that thought. Interactions of complex systems simply cannot be predicted far in advance with any accuracy. We cannot predict or force the occurrence of an idea any more than we can predict next week's weather. We cannot predict when a diseased brain will overreact violently to an inconsequential stimulus. We do know that one predictor of violence is a repetitive pattern of previous violent behavior. The most that can be said, however, is that a repetitive pattern of violent behavior increases the probability that future violence will occur.[98] Moreover, even among mentally ill populations with a history of past violence, experts are wrong in their predictions more often than they are right.[99] However, we also know that people whose mental illness is treated do not exhibit violent behavior more frequently than people without a history of mental illness.

The most that can be said about future dangerousness is a statement about the probability of a person with certain physical symptoms manifesting behavior outside the normal range. That is not to say that diagnosis of mental disorder is unfeasible. We can assess the probability that an individual has a mental disorder. Diagnoses of psychosis, schizophrenia, and the like are a matter of assessing these probabilities. There is little doubt that mental disorders like post-traumatic stress disorder and multiple personality disorder do exist, and that certain individuals do show all or most of the symptoms accompanying these disorders.

The issue in *Barefoot* was constitutional: could the state sentence the defendant to death based on scientifically questionable testimony? The Supreme Court decided that it could. The Supreme Court distinguished its decision in *Barefoot* from scientific evidence cases in which testimony about future dangerousness had been disallowed by explaining that Barefoot sought a constitutional rule barring an entire category of expert testimony.[100] The Court was "not persuaded that such testimony is almost entirely unreliable" and so found that the adversary

98. *See id.* at 922 (Blackmun, J., dissenting).

99. *See id.* at 920.

100. *Id.* at 899.

system would be competent to take account of its shortcomings.[101] Therefore, the Court found "no constitutional barrier to applying the ordinary rules of evidence governing the use of expert testimony."[102]

The ordinary rules of evidence governing the use of expert testimony have changed since *Barefoot*, however, and it is the Supreme Court's doing. Now the ordinary rules of evidence require that evidence be reliable in order to be admissible. Reliability in the context of scientific evidence requires scientific validity. It is doubtful that testimony about future dangerousness could withstand *Daubert* analysis. The point is not that *Daubert* overrules *Barefoot*. It does not. Rather, the point is that the conceptual underpinnings of *Daubert* are anathema to the result in *Barefoot*. Yet, the rule announced in *Barefoot* continues to be used without any attempt at subjecting it to a *Daubert* analysis.[103] The testimony in *Barefoot* certainly never received any such analysis, and predictions about future dangerousness were acknowledged to be wrong two out of three times. Moreover, given what we know about complex systems such as the brain and their interaction with other complex systems such as the world we live in, predicting future interactions can amount to little more than speculation.

Furthermore, mental disorder is treatable. Many disorders can, with treatment, bring behavior within the wide range of normal behavior. The brain is a physical organ and its function can be chemically altered. How such treatment will affect future behavior is, again, impossible to predict. We do know, however, that changing brain chemistry can widen the intervals between the times a person may end up in the ditches on the road of life.

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101. *Id.*

102. *Id.* at 904.

103. Of course, most criminal cases come before state courts, and a state court is not bound to follow *Daubert*, even if the state has adopted—as most have—rules of evidence modeled after the Federal Rules of Evidence. *See* Beecher-Monas, *supra* note 27, at 79. Thus, for example, although the Texas Court of Criminal Appeals explicitly recognized in *Jordan v. Texas*, 928 S.W.2d 550, 554 (Tex. Crim. App. 1996), that *Daubert* and the scientific validity standard it had adopted in *Kelly v. Texas*, 824 S.W.2d 568 (Tex. Crim. App. 1992), were substantially identical, Texas courts continue to allow testimony regarding future dangerousness without subjecting it to a strict *Daubert* analysis. *See, e.g.*, Nenno v. Texas, 970 S.W.2d 549, 561 (Tex. Crim. App. 1998) (holding that a *Daubert* analysis applies with "less rigor" to the "social sciences or fields that are based primarily upon experience and training as opposed to the scientific method").

Although there is a great deal about the brain and mental states that we do not understand, there are some things that scientists do know. The problem is that what is known is inconsistent with evidence the Supreme Court held admissible in two prominent cases on mental capacity. Lower courts cannot blindly accept pre-*Daubert* approved notions of expertise. Subjecting the lay and expert testimony in *Duckworth* and *Barefoot* to a *Daubert* analysis would reveal their flaws and render the testimony used inadmissible.

CONCLUSION

Two things become clear from juxtaposing Popperian precepts and what is known about the brain with the way courts are handling mental capacity testimony. First, judges must insist on the presentation of supporting data and coherent explanations of expert hypotheses. The probability that one event caused another increases or decreases depending on what evidence is available to support the theory. In order to assess the validity of the hypothesis, judges must require experts to present data and explain the way the hypotheses were tested.

Second, the Supreme Court needs to reconcile its conflicting jurisprudence on mental capacity testimony. Mental capacity is not a proper subject for lay testimony any more than cancer causation or tire failure. Nor does a methodology that frequently fails—because predicting complex interactions in a complex world is not feasible— pass gatekeeping muster. How it can be constitutional in a criminal case involving deprivation of life or liberty to admit expert testimony that could not pass gatekeeping muster in a civil suit is a question the Supreme Court has yet to resolve.

The brain is a complex system—non-linear, probabilistic, at the transition between equilibrium and non-equilibrium. Sanity is not an all-or-nothing proposition; it is a probablistic statement. Mental disorder is brain activity beyond the normal range of probabilities. However, a mentally ill individual will transition in and out of the normal range. At trial, the defendant may be driving on the right side of the road, but could have recently been in the ditch and will probably, if left untreated, return to the ditch. The experts should be testifying about those

probabilities and offer reasoned arguments for their conclusions. By realizing that science is about probabilities rather than causes, and by recognizing that an apt metaphor for mental state is the road of life, so that sanity is not an all or nothing issue, but a probabilistic statement, even a generalist judge can be better prepared to evaluate such testimony.

Figure 1

The Road of Life