HUMAN INFORMATION PROCESSING AND ADJUDICATION: TRIAL BY HEURISTICS

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This article addresses the role of quantitative evidence and methods in trials. Major arguments against the introduction of explicit computation information are considered and contrasted with findings about the characteristics of the unaided human decision maker. Emphasis is given to behavioral decision theory and the heuristic biases it reveals. Consideration is given to the symbolic versus "truth-finding" functions of trials, mathematical models (especially linear) of decision making, advocacy tactics that follow from what has been learned about how humans process information, the diagnostic value of aggregate probabilities, the notion of particularistic proof, and the evaluation of witness credibility. We conclude that unaided human decision making embodies certain normal and lawful errors, and that the exclusion of mathematical guides to aid a fact finder, while avoiding some problems, exposes the fact-finding process to the heuristic biases of intuitive decision making.

While a trial is many things, it most surely is a social invention for deciding between disputed alternatives under conditions of uncertainty. The values this invention seeks to maximize may be manifold and contradictory, but one of the most important among them is accuracy or correctness. Through legal decision making we seek to avoid the classic errors of convicting an innocent defendant or acquitting a guilty one, or finding liability when there is none or failing to find liability when it is present. Whatever justice may be, surely it is not error.

Various commentators have proposed, and various advocates have sought to introduce at trial, mathematical or statistical tools to guide the trier of fact and to reduce the number of inevitable errors (e.g., Baldus and Cole, 1979; Brown and Kelly, 1970; Cullison, 1969; Fairley and Mosteller, 1974; Finkelstein and Fairley, 1970; Kaplan, 1968; Meyer, 1973; Wigmore, 1940; EEOC Guidelines, V.29, Code of Federal Regulations, 1979: §§ 1607.1 and 1607.5[c]; Cohen, 1977, 1979, 1980; Schum, 1979). A limited amount of sharply reasoned and intriguing debate has taken place over these issues both in law reviews and in appellate courts (e.g., *People* v. *Collins*, 1968;

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Smith v. *Rapid Transit, Inc.*, 1945). Perhaps the most thorough critique of these proposals has been that of Lawrence Tribe in his article, "Trial by Mathematics: Precision and Ritual in the Legal Process" (1971). In that paper, Tribe seeks to persuade us that "the costs of attempting to integrate mathematics into the factfinding process of a legal trial outweigh their benefits" (1971: 1393).

Tribe does not object to the introduction of quantitative evidence, though he is decidedly wary of it and its aroma of certitude. What he advocates is that such data be used, if they must, in their most descriptive and raw form, that the judge or jury not be told how these data might be analyzed and what inferences might be drawn from the results of such analysis. The kinds of analysis and mathematical models used by all sorts of scientists, engineers, administrators, planners, and others in order to put questions to their data is what Tribe would ban from legal fact finding. His objections to such mathematizing of evidence are based on his opinion that it leads to imprecise estimates that are inevitably probabilistic, that soft variables are dwarfed in favor of more easily quantifiable variables, that it is difficult to apply background probability estimates to deciding specific instances, and that the trial process would be dehumanized. Tribe argues, in essence, that keeping a trial as intuitive, as elemental, as the Anglo-Saxon trial can be will preserve the symbolism and humanness, thereby best serving the courts and society.

In a fundamental criticism of using the somewhat more precise language and meaning of mathematics, Tribe eloquently defends the value of legal symbolism and the resulting mask of certainty.

> The system does *not* in fact authorize the imposition of criminal punishment when the trier recognizes a quantifiable doubt as to the defendant's guilt. Instead, the system dramatically—if imprecisely—insists upon as close an approximation to certainty as seems humanly attainable in the circumstances. The jury is charged that any "reasonable doubt," of whatever magnitude, must be resolved in favor of the accused. Such insistence on the greatest certainty that seems reasonably attainable can serve at the trial's end, like the presumption of innocence at the trial's start, to affirm the dignity of the accused and to display respect for his rights as a person—in this instance, by declining to put those rights in deliberate jeopardy and by refusing to sacrifice him to the interests of others.
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> In contrast, for the jury to announce that it is prepared to convict the defendant in the face of an acknowledged and numerically measurable doubt as to his guilt is to tell the accused that those who judge him find it preferable to accept the resulting risk of his unjust conviction than to reduce that risk by demanding any further or more convincing proof of his guilt.
>
> . . . That some mistaken verdicts are inevitably returned even by jurors who regard themselves as "certain" is of course true but is irrelevant; such unavoidable errors are in no sense *intended*, and the fact that they must occur if trials are to be conducted at all need not

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> undermine the effort, through the symbols of trial procedure, to express society's fundamental commitment to the protection of the defendant's rights as a person, as an end in himself. On the other hand, formulating an "acceptable" risk of error to which the trier is willing deliberately to subject the defendant would interfere seriously with this expressive role of the demand for certitude—however unattainable real certitude may be, and however clearly all may ultimately recognize its unattainability (1971: 1374).

A trial may indeed be more than a search for the truth in a given matter; but surely it is not less. We will seek to demonstrate, contrary to Tribe, that while certain errors and harm may be inherent even in the proper use of probabilistic tools, even more harm may be inherent in not using them.

The present paper has two aims and consequently is divided into two major sections. The first aim is to cast altogether new light on this debate by challenging Tribe's assumptions from an empirical point of view. We will do this by presenting the conclusions of a family of theories of human decision making known as "behavioral decision theory" and some of the empirical research findings on which they stand. These are fascinating in themselves and highly relevant to the question of whether intuitive decision making by humans and explicit calculation of probabilities will lead a trier of fact closer to the correct conclusion.

Influential as Tribe's paper has been, like much legal scholarship, it is a Swiss cheese of assumptions about human behavior[1]—in this case human decision-making processes—which are asserted as true simply because they fall within the wide reach of the merely plausible, not because any evidence is adduced on their behalf. The present article makes available to this important and increasingly unavoidable debate some important findings about human decision processes and their implications for the trial process and for the role of mathematical tools in the fact-finding portion of that process. While the other debaters have focused on mathematics and make facile assumptions about what humans do with such information, we focus on the human decision-making

[1] Consider the following examples: people have great difficulty translating their subjective feeling of certainty into statements of probability (at 1358). Presented with a "mathematically powerful intellectual machine," people will tend to disregard soft nonquantifiable variables in favor of quantified variables (Tribe, 1971: 1360-1362). When jurors vote to convict, many/most would describe their state of mind as "completely sure" or "as sure as possible" (Tribe, 1971: 1374). In the face of quantitative data, few jurors will perform or even recall their "humanizing function, to employ their intuition and their sense of community values to shape their ultimate conclusions" (Tribe, 1976: 1376). These premises, sometimes important to Tribe's thesis, stand without any supporting evidence. If these seem picky, consider this major thesis: that symbolic functions of the trial are often more important than accurate fact finding. This too stands without evidence.

machinery. By enumerating its characteristic problems, we invite legal policy makers and other observers to decide not between flawed mathematics and unspecified, black-box human cognitive processes, but between two imperfect systems for reaching decisions.

The second goal of this article is to explore still other implications of these findings for the trial process, going even to its fundamental structure. These implications include the effect of the trial's format on the fact finder's subjective certainty of guilt, the costs of relying upon human intuition, the unstoppable growth of scientific and technical evidence in trials, the limited influence on fact finders of statistical relative to anecdotal information, the question of whether particularistic information really exists for the legal fact finder, the associated problem of applying background base-rate probabilities to reaching decisions in specific instances, the problem of evaluating witness credibility, and the use of heuristic biases by lawyers to be more persuasive trial advocates.

I. DECISION MAKING UNDER UNCERTAINTY

Most legal decision making, like that in many other areas of complex activity, is done under conditions of uncertainty.[2] Events must be classified, predicted, or post-dicted in circumstances where the correct choice is more probable than zero but less probable than unity. If one wished to choose a given product with the lowest unit price, the fastest transit route between two cities, or which manner of calculating one's taxes results in the least liability, one could, through proper information gathering and analysis, identify the correct solution with certainty (or something bordering on certainty). Other problems, by virtue of their complexity, the limitations of available information, or the inadequacy of our conceptualizations for dealing with them, have best solutions that cannot be known with certainty to be correct. Judges and jurors are called upon, for example, to assess the likelihood that a witness's report is congruent with the actual event; the probability, given certain evidence, that a defendant committed

[2] One of the simplest ways to think about uncertainty is to consider predicting a simple event. If the event (say, the sun shining tomorrow) *always* occurs, we would be certain it will happen ($p = 1.00$); if it *never* occurs, we would be certain it will not happen ($p = 0.00$); if it occured 60 percent of the time, our confidence in predicting its next occasion would reflect something other than certainty, and our prediction would most likely reflect the relative frequency of occurrence ($p = 0.60$). See Raiffa, 1968; Savage, 1950.

an alleged offense; the risk of harm that reasonably should have been foreseen as associated with certain design features of a product; the probability that a pollutant caused certain damage; or the likelihood that a person in jeopardy of civil commitment is dangerous to self or others.[3] Thus, the nature of the questions and the information available to judicial decision makers defines their task as an uncertain and probabilistic one.[4]

Abundant evidence from psychological research, however, suggests that in many contexts decision makers' intuitive, common-sense judgments depart markedly and lawfully (in the scientific sense) from the actual probabilities. People use a number of simplifying operations, called "heuristics," to reduce the complexity of information which must be integrated to yield a decision. These simplifying strategies often lead to errors in judgment. Consider the following examples:

> 1. After observing three consecutive red wins, a group of people playing roulette start to switch their bets to black. After red wins on the fourth and fifth spins, more and more players switch to black, and they are increasingly surprised when the roulette wheel produces a red win the sixth, and then the seventh time. In actuality, on each spin the odds of a red win remain constant at 1:1. The shifting of bets to black was irrational, as was the strong subjective sense that after each successive red win, black became more likely.
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> 2. The following description is of a man selected at random from a group composed of 70 lawyers and 30 engineers. "John is a 39-year-old man. He is married and has two children. He is active in local politics. The hobby that he most enjoys is rare book collecting. He is competitive, argumentative, and articulate." A large group

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[3] Many of the rules of evidence and procedure are designed precisely to deal with the uncertainty of knowledge that guides adjudications, most evident in the standard of proof required to reach a finding. When the available information comes to be recognized as systematically defective, the standard of proof has been lowered to meet it (*Addington* v. *Texas* [1979]).

[4] That probabilistic thinking is inherent in the law and familiar to lawyers is evident from even a casual reading of the notes and commentaries to the Federal Rules of Evidence or the lawyer's role as defined by the Code of Professional Responsibility:

> In serving a client as adviser, a lawyer in appropriate circumstances should give his professional opinion as to what the ultimate decisions of the courts would *likely* be as to the applicable law.
>
> The advocate may urge any permissible construction of the law favorable to his client, without regard to his professional opinion as to the *likelihood* that the construction will ultimately prevail [Emphasis added] (ABA Code of Professional Responsibility EC7-3 and 7-4).

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of respondents was asked to estimate the probability that John is a lawyer rather than an engineer. Their median probability estimate was .95. Another group of respondents was asked the same question, except that they were first told that the group from which John was selected consisted of 30 lawyers and 70 engineers. The second group's median estimate of the likelihood that John is a lawyer was also .95. Information about the composition of the group from which John was selected logically should have affected the estimated probability, but it had no effect at all on the decision makers' judgment. (This problem is taken from Kahneman and Tversky, 1973.) Only at the extremes of the distributions, where the group approaches 100 lawyers and 0 engineers (or the converse) do the decision makers become sensitive to the information about group composition.

3. A cab was involved in a hit-and-run accident at night. Two cab companies, the green and the blue, operate in the city. A witness reports that the offending cab was blue, and legal action is brought against the blue cab company. The court learns that 85 percent of the city's cabs are green and 15 percent are blue. Further, the court learns that on a test of ability to identify cabs under appropriate visibility conditions, the witness is correct on 80 percent of the identifications and incorrect on 20 percent. Several hundred persons have been given this problem and asked to estimate the probability that the responsible cab was in fact a blue cab. Their typical probability response was .80. In actuality, the evidence given leads to a probability of .41 that the responsible cab was blue.[5] (This problem is taken from Tversky and Kahneman, 1980.)

The first example illustrates the simplest and best known of errors in human probability judgment, the "Gambler's Fallacy." In a sequence of independent events, outcomes of prior events do not affect the probability of later events. Each event is independent of the other. On the seventh spin, the

[5] The indispensability of such base rates to making sense out of evidence is not recognized in the law, but it is elsewhere. In medicine, for example, laboratory tests constitute a major source of evidence for decision making. Each test has a known or knowable "sensitivity" and "specificity." Specificity means the probability that a person who is said by the test not to have a disease actually does not have it. Sensitivity means the probability that a person who is said by the test to have a disease actually does have it. These parameters tell us the probable accuracy of the test results in an individual case, and the accuracy "is related fundamentally to the incidence [i.e., base rate] of the disease" (Krupp *et al.*, 1979; Krieg *et al.*, 1975).

roulette wheel neither remembers nor cares what it did on the preceding six spins. People know that in the long run, half the wins will be red and half black. They err in believing that a small local sequence of events will be representative of the infinite sequence. "Chance is commonly viewed as a self-correcting process in which a deviation in one direction induces a deviation in the opposite direction to restore the equilibrium. In fact, deviations are not 'corrected' as a chance process unfolds, they are merely diluted" (Tversky and Kahneman, 1974). Although intuition in this context is out of harmony with reality, we all feel it compellingly, and continue to hear that baseball players who have not had a hit in some time are "due" for one, and that lightning will not strike twice in the same place.[6] These common-sense judgments are, nevertheless, dead wrong.

The second example illustrates how human decision making tends to be insensitive to base rates when case-specific information is available.[7] Given only the group base rates—30 lawyers: 70 engineers—people rely heavily on this information to make their judgments. They correctly say the probability is .30 that the person selected is a lawyer. When descriptive case-specific information is added, they tend to ignore the numerical base rate and rely instead on the degree to which the description of John is representative of their stereotype of lawyers. Subjects base their estimate of the probability that John is a lawyer on the degree of correspondence between his description and their stereotype of lawyers as argumentative, competitive, and politically aware. Given the base-rate data in this example, it is 5.44 times as likely that John is a lawyer when the group is composed of 70 lawyers and 30 engineers than when the opposite membership distribution holds.[8]

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[6] This reflects belief in a "law of small numbers," even though nature's design is limited to the "law of larger numbers" (i.e., as sample sizes become increasingly large, they will more closely approach the parameters of the population; the "law" of small numbers would hold that this works also for small samples) (Tversky & Kahneman, 1971).

[7] Note that this is precisely the opposite of what is assumed by many commentators (*cf.* Tribe, 1971).

[8] The solution may be calculated by Bayes' rule, in odds form. The rationale is not complicated. The person is either a lawyer or an engineer. The odds that he is a lawyer are 70:30, that he is an engineer, 30:70. The ratio of the former odds to the latter is

$$\frac{\frac{70}{30}}{\frac{30}{70}} = \left(\frac{70}{30}\right)^2 = 5.44.$$

For a discussion of Bayes' Theorem, see Finkelstein and Fairley, 1970.

The third example also demonstrates insensitivity to base-rate information, this time in a context where both the base-rate and the case-specific information are given numerically. The actual low probability that the cab is blue is due to the fact that the base rate for blue cabs is very low, and the witness is of dubious acuity. Indeed, the base rate is more extreme than the witness is credible. But, fact finders apparently are unable simultaneously to relate the color of the hit-and-run cab to two different concerns, namely, the sampling of cabs from the city's cab population and imperfect color identification by the witness. They ignore the base-rate information and treat the accuracy of the witness as equal to the probability of a correct identification.[9]

These illustrations demonstrate the gap between the judgments people make intuitively and the probabilities yielded by explicit calculation (or by empirical observation of actual outcomes[10]). People do not always err, but in particular decision making situations they tend predictably to be incorrect. Because these errors of intuition are systematic and lawful, they are called biases. Because these biases result from the simplifying strategies used by decision makers, whose

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[9] Again, by Bayes' rule,

$$\frac{P(B/W)}{P(G/W)}$$

that is, the ratio of the probability that the cab was blue, given the witness's statement; to the probability that the cab was green, given the witness's statement

$$= \frac{P(W/B)\ P(B)}{P(W/G)\ P(G)} = \frac{(.8)\ (.15)}{(.2)\ (.85)} = \frac{.12}{.17}$$

$$P(B/W) = \frac{.12}{.12 + .17} = .41$$

Graphically,

		In reality, cab is G	B	
Probability W is	Right	.68	.12	.80
	Wrong	.17	.03	.20
		.85	.15	

Thus, given that W says "the cab was blue," there is a probability of .12 that the cab was blue and the witness is right, and a probability of .17 that the cab was green and the witness wrong. Thus, given that the witness says "blue," the probability is .12/(.12 + .17) = .41 that the cab was in fact blue.

[10] If the actual experiments were carried out, and some have been, the empirical observations would confirm, and have confirmed, the explicit calculation rather than the implicit judgment. That such "statistical" decision making is more accurate than "clinical" judgment, is a well settled question (Meehl, 1954; Sawyer, 1966).

cognitive capacities cannot otherwise efficiently process the information, they are known as heuristic biases.[11]

These heuristic biases are not limited to decision making in legal contexts, nor are they limited to the simple illustrations cited above. The same errors have been observed for bankers and stock market experts predicting closing stock prices (Von Holstein, 1972; Slovic, 1969), for Las Vegas casino patrons making bets (Lichtenstein and Slovic, 1971, 1973), for psychiatrists and clinical psychologists predicting behavior (see reviews in Meehl, 1954; Mischel, 1968), for statistically sophisticated researchers estimating statistical values (Brewer and Owen, 1973; Cohen, 1962; Tversky and Kahneman, 1971), for military intelligence analysts (Brown *et al.*, 1974), for engineers estimating repair time for inoperative electric generators (Kidd, 1970), for flood plain residents estimating the probability of floods (Slovic *et al.*, 1974), for physicians making diagnoses and prognoses (Einhorn, 1972; Gilbert *et al.*, 1977), and in business decision making (Bowman, 1963). One can summarize these diverse findings by concluding that "people systematically violate the principles of rational decision making when judging probabilities, making predictions, or otherwise attempting to cope with probabilistic tasks" (Slovic *et al.*, 1976).

In many areas, decision aids are being developed to compensate for the fact that ". . . man's cognitive capacities are not adequate for the tasks which confront him" (Hammond, 1974). These aids range from the advice to engage in explicit calculation of probabilities (Tversky and Kahneman, 1971; Kahneman and Tversky, 1979), to decision analysis (Howard *et al.*, 1977; Raiffa, 1968; Schlaifer, 1969), to human/machine systems (Davis *et al.*, 1975; Edwards, 1962; Hammond, 1971; Hammond *et al.*, 1975). We hope it is not unduly optimistic to suppose that the law could be another area in which less than reliable, less than accurate decision making can be identified and corrective strategies developed.

We now turn to a closer examination of decision heuristics—what they are, why they exist, their impact on human judgment, and their implications for decision making in legal contexts.

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[11] A heuristic is a strategy, usually a simplifying strategy, which provides aid and guidance in solving a problem. A heuristic is the opposite of an algorithm. In deciding what move to make in a chess game, one could systematically consider and evaluate every possible move. This would be an algorithmic strategy. Or one could evaluate only the positions of pieces in the center of the board and the most important pieces. That would be a heuristic strategy.

II. HEURISTICS

The leading research in decision heuristics is that of Amos Tversky and Daniel Kahneman.[12] These two research psychologists have identified a limited number of principles which seem to guide the simplification of complex information-processing tasks. For many purposes these simplifying heuristics result in reasonable judgments; however, they often lead to distorted and systematically erroneous decisions. The three fundamental heuristics involved in making probabilistic judgments are: representativeness, availability, and anchoring and adjustment.

Representativeness

Often probability statements concern the likelihood that an event, behavior, or object originated from or caused another event, behavior, or object. For example, what is the probability that person P committed a murder, given that his fingerprints are found on the murder weapon? What is the probability that a firm intended to discriminate in hiring, given that none of its 14 employees is a member of an ethnic minority? In answering some of these types of questions, people sometimes rely on the representativeness heuristic.

With this "cognitive shorthand," people assess the likelihood that event A causes or is associated with event B by the degree to which A is representative of B, or in other words, the degree to which A resembles B. People connect events A and B by assessing the degree of similarity between them. This assessment invariably leads to the inference that A and B are connected probabilistically simply because they bear some resemblance to each other in terms of their descriptive features. For a great many purposes, this is a useful strategy—namely, those occasions when probability is highly correlated with similarity. One might choose livestock by assessing the degree to which the offspring are similar to other animals that grew to be prized adults. One might admit applicants to law school by assessing the degree to which they are similar to others who were successful in the past.

But judging the probability of an event based on its similarity to or representativeness of other events may lead to defects in judgment, because similarity is not influenced by

[12] We have borrowed heavily from these researchers, and must credit them with the basic discoveries. We have applied these findings to legal concerns, and any errors in doing so are ours. For some of their original research reports, see Kahneman and Tversky, 1972, 1973; Tversky, 1975; Tversky and Kahneman, 1971, 1973, 1974, 1980.

facts that should affect probability judgments. One major factor that should affect probability judgments is the *prior probability* or the prior frequency of the occurrence of an event. In the example of the cab accident, the subjects' likelihood estimates were not affected by the fact that only 15 percent of the cabs in the hypothetical city were blue. This prior probability makes it much more likely that the hit-and-run accident was committed by a green cab.

A common example of this kind of information in court arises from evidence presented by experts in scientific or technological fields. Many of the facts typically presented, which can be highly diagnostic for the fact finder, are of this probabilistic sort: the risk of death due to anesthesia is 1 in 5,000; a palmprint of a particular type occurs with a frequency of 1 in 1,000; one-third of suicide victims leave a note. Particularly well studied are the errors made by psychiatrists and clinical psychologists (and then judges) in predicting dangerousness (Ennis and Litwack, 1974; Steadman and Cocozza, 1974; Ziskin, 1975). The consistent overprediction of dangerousness is in part due to experts' insensitivity to the low frequency of such behavior and reliance on the representativeness heuristic wherein the person threatened with commitment is compared to the stereotype of a dangerous person (Kahneman and Tversky, 1972). The greater the degree of similarity, the greater the clinician's confidence in predicting dangerousness. But, however much person P may resemble the clinician's stereotype of the dangerous person, the extremely low base rate of violent behavior (either in the population or for this individual) means that the probability that person P will be violent is very low. Clinicians' errors are thus expected to be high and in the direction of massive overprediction of dangerousness (Dershowitz, 1968; Livermore *et al.*, 1968; also see references in Ennis and Litwack, 1974; Ziskin, 1975).

In addition to uses (or should we say non-uses?) of base-rate information for deciding conventional cases in the courts, we find growing numbers of scientific and technological cases. These include litigation in the areas of antitrust, economic programs, nuclear regulation, products liability, environment and pollution, rate making, new drugs, consumer law, energy policy, and others.[13] Many of these cases are appeals from

[13] See the recent bibliography, Cohen *et al.*, 1978, especially the sections on Science and the Adjudicatory Function of Law, Computers, Medicine, Public Health and Safety, Natural Resources and Environmental Controls, and Science and International Law.

regulatory agency decisions, in which the very meaning of the data is at issue. (See, e.g., *Essex Chemical Co.* v. *Ruckelshaus*, 1973; *Ethyl Corporation of America* v. *EPA*, 1976; *Greater Boston Television Corp.* v. *FCC*, 1970; *International Harvester Co.* v. *Ruckelshaus*, 1973; *Portland Cement Association* v. *Ruckelshaus*, 1973; also see Stewart, 1975; Bazelon, 1977.) In all of the kinds of cases mentioned, base-rate information—the form in which many legislative facts often exist (e.g., *Ballew* v. *Georgia*, 1978; *Gregg* v. *Georgia*, 1976; and cases cited above; also see Leventhal, 1974)—is typically presented as evidence along with case-specific information. As we have seen, the base-rate information, despite its considerable value to rational decision making, is likely to be given less weight when the fact finder has to integrate it with case-specific information.

Some solutions have already been proposed for the law. Perhaps the minimum solution is already present: allowing the information to be testified to by experts (Federal Rules of Evidence 702, 703, 704, 705). Clever experts could turn the representativeness heuristic to advantage in their testimony or appendices to briefs by supplementing their base-rate information with anecdotal examples or illustrations, which are more case-specific and hence ought to be more persuasive to the heuristic decision maker. Another suggestion has been to have an additional expert—for example, a statistician—give the fact finder guidance in what the base-rate evidence means or how it can be combined optimally with whatever the fact finder thinks about the case-specific information (Finkelstein and Fairley, 1970). Some commentators have taken so seriously the general problem of handling scientific and technical data in the courts that they have suggested more extensive solutions, such as special masters (Beuscher, 1941; Federal Rules of Civil Procedure 53; *LaBuy* v. *Howes Leather Co.*, 1957; *Avco Corp.* v. *A.T.T.*, 1975; *Vermont* v. *N.Y.*, 1974; *U.S.* v. *I.B.M.*, 1976; *Omnium Lyonnais D'Etancheite* v. *Dow Chemical Co.*, 1977; *Hobson* v. *Hansen*, 1971), court advisers (e.g., *Reserve Mining* v. *U.S.*, 1975; Federal Rules of Evidence 706), and special courts.

Another important variant of the representativeness heuristic is human *insensitivity to sample size*. In the world of reality, larger samples are more likely than smaller samples to approximate the characteristics of the population from which they were drawn. "This fundamental notion of statistics is evidently not part of people's repertoire of intuitions" (Tversky and Kahneman, 1974: 312). A clear instance of this error in judicial policy making is provided by the U.S. Supreme Court in *Williams* v. *Florida* (1970). In deciding whether reductions in jury size from twelve to six would reduce the jury's ability to provide a representative cross-section of the community, the court concluded:

> [W]hile in theory the number of viewpoints represented on a randomly selected jury ought to increase as the size of the jury increases, in practice the difference between the twelve-man and the six-man jury in terms of the cross-section of the community represented *seems* likely to be negligible [emphasis added] (*Williams* v. *Florida*, 1970: 101).

The Court's intuitive sampling theory was found to be in error when compared to explicit calculation. For example, sampling randomly from a community composed of a stratified population (90 percent one group and 10 percent another), 72 percent of 12-person juries would include at least one member of the minority while only 47 percent of six-person juries would include at least one minority person (Saks, 1977; Zeisel, 1971; *Ballew* v. *Georgia*, 1978). In this example, the "negligible" difference is 25 percent. Because intuitive decision makers expect samples of any size to be representative of the population from which they originate, they will often be wrong.

The *illusion of validity* is a third example[14] of the representativeness heuristic. As shown above, people tend to make intuitive predictions by selecting the outcome that is more similar to their stereotype. People express great confidence in such predictions, ignoring factors which limit predictive accuracy. Given a brief personality description, people rely on their stereotypes, or implicit personality theory,[15] and go from the description—however scanty, unreliable, or outdated—to the prediction.[16] Even when decision makers are knowledgeable about the factors limiting the accuracy of predictions, their intuitions press them compellingly toward error.

> It is a common observation that psychologists who conduct selection interviews often experience considerable confidence in their predictions, even when they know of the vast literature that shows

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14 Other kinds of representativeness heuristics the human mind is heir to include misconceptions of chance, insensitivity to predictability, and misconceptions of regression. See Tversky and Kahneman, 1974.

15 "Implicit personality theory" is the set of beliefs each person holds concerning the behavior and personality of others—that is, which characteristics occur together, predict other characteristics, predict behavior, etc. One's implicit personality theory will be partly culturally determined, partly idiosyncratic, but in any case is an untested, unconfirmed collection of ideas that people rely on to explain or predict others. See Bruner and Tagiuri, 1954.

16 That is, they do not take into account the inaccuracy of their implicit personality theories.

selection interviews to be highly fallible. The continued reliance on the clinical interview for selection, despite repeated demonstrations of its inadequacy, amply attests to the strength of this effect (Tversky and Kahneman, 1974: 1126).

One of the major determinants of the strength of the illusion (i.e., the degree of unwarranted confidence) is the pattern of internal consistency among the inputs. If the information on which the conclusion is based is seen as highly consistent (it all "points in the same direction" or "hangs together"), the decision maker's confidence in the stereotype's accuracy is greatly increased. Unfortunately, this pattern of consistency will often be the result of redundant information, rather than additional information. When actual data are collected to develop predictive models, as by social scientists and others, the elementary statistics of correlation show that input variables that are highly correlated, or redundant, do not improve the accuracy of the prediction. Predictions achieve greater accuracy when they are based upon informational inputs which are independent of each other. "Thus, redundancy among inputs decreases accuracy even as it increases confidence, and people are often confident in predictions that are quite likely to be off the mark" (Tversky and Kahneman, 1974: 1126).

The skillful attorney may trade on this defect of intuition by trying to paint a consistent personality picture of a party to a case, whether it be through character testimony, through other evidence, or in argument. Given our susceptibility to such illusions of validity, the rules of evidence are fortunate in their exclusion of evidence of "character" traits.[17] And, while FRE 403 excludes the "needless presentation of cumulative evidence" because it wastes time, the rule will also tend to avoid the problems inherent in increasing fact finders' confidence without increasing their accuracy. We should note, however, that FRE 403 asserts that such evidence is relevant, but should be excluded anyway. To the extent that evidence is redundant, it is *not* relevant, that is, it does not have "any tendency to make the existence of any fact . . . more probable or less probable than it would be without the evidence"— except subjectively (Federal Rules of Evidence 401; also see Lempert, 1977). And that, of course, is the very issue on which the illusion of validity principle casts light. Redundant

[17] Federal Rules of Evidence, Rule 404. While the rule excludes "character" evidence for reasons of relevancy, it has the corollary advantage of avoiding the activation of character-behavior stereotypes, which are strong, and the likely impact of illusory validity on the fact finder.

information makes certain facts *seem* intuitively more probable, but in actuality it does not increase their likelihood.

Availability

A second heuristic discussed by Tversky and Kahneman is availability. According to this heuristic, people are likely to judge the probability or frequency of an event based on the ease with which they can recall instances or occurrences of the event. Availability, as noted by these researchers, may be a helpful cue when assessing probability, because events that are more frequent may be recalled more readily than events that occur less frequently. However, factors other than simple objective frequency may affect intuitive probability estimates.

> In an elementary demonstration of this effect, subjects heard a list of well-known personalities of both sexes and were subsequently asked to judge whether the list contained more names of men than of women. [In actuality, the numbers of men and women were equal.] Different lists were presented to different groups of subjects. In some of the lists the men were relatively more famous than the women, and in others the women were relatively more famous than the men. In each of the lists, the subjects erroneously judged that the class (sex) that had the more famous personalities was the more numerous (Tversky and Kahneman, 1974: 1127).

Because they were more readily available to memory, people thought they were more numerous, and consequently made erroneous judgments. Factors such as familiarity, salience, and recency of the occurrence of the event affect the retrievability of information and enhance the potency of the availability heuristic.

The availability heuristic raises important concerns for the presentation of certain kinds of evidence to a fact finder. The subjective estimates of the likelihood that a particular event did occur or that particular consequences would follow from certain actions will be influenced not only by the actual frequencies of those events, but by their availability in memory. Expert witnesses reporting scientific and/or statistical data are likely to have less impact on a fact finder than does a person who reports a case study, relates a compelling personal experience, or offers anecdotal evidence. That which is more concrete, vivid, emotion-arousing, and otherwise more salient will be more accessible when a fact finder ponders the decision to be made (Nisbett *et al.*, 1976).

Using this lesson ourselves, we offer the following two anecdotal illustrations. We have two colleagues who are experts on the psychology of eyewitness identification and occasionally testify in criminal trials. She testifies as the scholar, describing factors affecting sensation and perception, storage, retention, and retrieval, memory decay curves, and the findings of experimental research on perception and memory. He presents a slide show in which he explains a few things about the psychology of perception and memory, shows more pictures and fewer graphs, tells some stories about faulty police procedures and eyewitness inaccuracy, and most important of all, by way of the slide show gives jurors an opportunity to experience their own perceptual errors.[18] In terms of persuading juries to be more skeptical of eyewitness testimony, he is a more successful expert than she. The salience of their own experience is more persuasive to jurors than data reporting on the behavior of many others.

Assumptions about the way people think leads lawyers to plan particular trial strategies. Erroneous assumptions may lead to ineffective or counterproductive strategies. In one recent case (*Mashpee Wampanoag Indians* v. *Assessors*, 1980), a critical issue was whether plaintiff Native Americans did indeed constitute a tribe. The plaintiffs had their expert, an anthropologist armed with anecdotal observational evidence, and the defense had theirs, a sociologist with computer analyzed survey data. Fearing the overpowering effect of the sociologist's quantitative data, the plaintiffs moved to have the data excluded. On persuading the judge that the data were flawed by methodological and analytic errors, the plaintiffs succeeded in having the defense expert limited to testifying only to her anecdotal personal observations. We believe the plaintiff's strategy was a mistake on two counts. First, based on what we know about the availability heuristic, we would predict that the quantitative data of the sociologist would have been *less* persuasive than the anthropologist's anecdotal report, because the latter would generally be more concrete and salient, and therefore more accessible. Second, and somewhat beside the present point, if the data were flawed, then exposing it to adversary cross-examination would lead the jurors to give it even less weight than their own cognitive processing would normally have given it. The plaintiffs threw away an opportunity to expose the flaws in the defense data and won a motion requiring the defense expert to give only the more salient evidence. The defense won.

Beyond issues concerning the presentation of evidence, judges making sentencing and commitment decisions use heuristics. Instead of relying on all of the events in their

18 Part of one's confidence may stem from a lack of reality testing, or sloppy testing.

experience, the availability principle tells us they will more readily recall and therefore believe to be more probable, the more salient experiences. Experiences are more likely to be salient because they are bizarre or exteme. Thus, they are the poorest instances on which to construct decision-making policies.

For example, physicians making rational treatment decisions should consistently play the odds established by empirical research or long experience. Instead they have been found to deviate in their treatment recommendations as a function of recent, salient, more cognitively available experiences. In particular conditions Treatment A may be the choice over Treatment B. But, if the last few times the physician prescribed A it failed to work, on the next few decisions that physician will (irrationally) shy away from prescribing it (Bowman, 1963; Dawes and Corrigan, 1974; Dawes, 1979; Goldberg, 1970; Wiggins and Kolen, 1971). This will, of course, hold for any decision maker relying on intuitively derived probabilities—physicians, football coaches, stockbrokers, lawyers, and judges. It is nearly always instructive for decision makers to compare their subjective impressions to data objectively summarizing the actual events they are deciding about. Reality usually holds some surprises.[19]

Another[20] interesting kind of error based on the availability principle is the notion of *illusory correlation* (Chapman and Chapman, 1967, 1969), a bias in the judgment of the frequency of co-occurrence of two events. An illusory correlation is a report by an observer of a correlation between two classes of events which in reality (a) are not correlated, (b) are correlated to a lesser extent than reported, or (c) are correlated in the opposite direction of that which is reported (Chapman and Chapman, 1967, 1969; Tversky and Kahneman, 1974).

In many areas of judgment, people are asked to estimate co-occurrences, such as that between personality characteristics and patterns of behavior. For instance, judges instruct jurors to rely on their life experiences to assist them in judging the credibility of witnesses, assigning weight to testimony, and so on. In the case of an illusory correlation, a person's estimate of co-occurrence departs systematically from

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[19] By "reality" we do not mean to become entangled in philosophical undergrowth. We mean simply what is observable, what may be empirically confirmed—as opposed to what we may speculate on or hope or wish to be true.

[20] The various kinds of availability heuristics include biases due to the retrievability of instances, biases due to the effectiveness of a search set, biases of imaginability, and illusory correlation (Tversky & Kahneman, 1974).

the evidence they actually experience. In one study of this phenomenon researchers provided subjects with clinical diagnoses and drawings of a person made by hypothetical psychiatric patients. The subjects were asked to estimate the correlations between certain diagnoses and features of the patients' drawings. Many of the correlations they reported perceiving—such as size and emphasis on the eyes being associated with diagnoses of paranoia and suspiciousness—reproduced much of the common but unsubstantiated clinical lore concerning the interpretation of such drawings. People "perceived" these stereotypical correlations even though there was no evidence for them. Indeed, the illusory correlations were so resistant to contradictory evidence that they persisted even when the actual correlation between diagnosis and symptom was negative. Moreover, the illusory correlations prevented subjects from detecting relationships that actually were present.

An availability interpretation of this phenomenon would be that the judgment of covariation between the two events (the diagnosis and the drawing) is determined simply by the stereotypic association between these two events. The stronger the assumed association between the two, the more likely it is judged that they will co-occur. The nature and strength of the association flow from cultural norms, stereotypes, or observers' direct experience with a limited number of similar events. Like similar effects we have discussed, the more cognitively available associates are not necessarily the ones that actually occur at a high frequency or, indeed, with any frequency at all.

> Lifelong experience has taught us that, in general, instances of large classes are recalled better and faster than instances of less frequent classes; that likely occurrences are easier to imagine than unlikely ones; and that the associative connections between events are strengthened when the events frequently co-occur. As a result, [people have] at [their] disposal a procedure (the availability heuristic) for estimating the numerosity of a class, the likelihood of an event, or the frequency of co-occurrences, by the ease with which the relevant mental operations of retrieval, construction, or association can be performed. However, as the preceding examples have demonstrated, this valuable estimation procedure results in systematic errors (Tversky and Kahneman, 1974: 1128).

Adjustment and Anchoring

To round out our discussion of heuristics we will mention two final rules. These decision heuristics are known as adjustment and anchoring. When making certain types of judgments, people often start with an initial estimate and then make adjustments or revisions of these initial estimates.

However, it is often the case that the adjustments depend heavily on initial values.[21] It is not surprising that different initial values often lead to different final estimates. This phenomenon is known as anchoring.

To illustrate the anchoring principle two groups of high school students were given one of two problems to solve. One group was asked to estimate, without the aid of paper and pencil, the product of the following sequence:

$$8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = ?$$

The other group was asked to estimate the product of these same numbers presented in ascending order.

Usually the students simply multiplied together the first two or three numbers and then extrapolated from this product to the final guess. If this is indeed how they performed the calculations to arrive at a final product, then the anchoring principle should have caused the first, descending group to judge the final product as larger than the second, ascending group. In fact, this was the case. The median estimate for the ascending sequence was 512, while the median estimate for the descending sequence was 2,250. The correct answer is the same in both cases, 40,320. This illustrates *insufficient adjustment* from the initial anchor (Slovic and Lichtenstein, 1971).

Trivial in its obviousness is the suggestion that fact finders asked to estimate amounts should be expected to insufficiently adjust from the initial anchoring quantity they receive. Systematic errors are likely to occur, and clever advocates could turn this heuristic to forensic advantage.

A more intriguing aspect of the adjustment and anchoring heuristic has to do with *biases in the evaluation of conjunctive and disjunctive events*. A study by Bar-Hillel (1973) clearly illustrates the matter. Subjects could bet on several kinds of events:

a. simple events (e.g., drawing a red marble from a bag containing 50 percent red marbles and 50 percent white marbles).

b. conjunctive events (e.g., drawing a red marble seven times in succession, with replacement, from a bag containing 90 percent red marbles and the rest white).

c. disjunctive events (e.g., drawing a red marble at least once in seven successive tries, with replacement, from a bag containing 10 percent red marbles and the rest white).

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[21] *Cf.* Tribe, 1971: 1358, 1359, on "the elusive starting point."

In the above examples, a significant majority of subjects preferred to bet on the conjunctive event over the simple event, and the simple event over the disjunctive event. Actually, the conjunctive event has a .48 probability of occurrence, the simple event a .50 probability, and the disjunctive event a .52 probability. In making both choices, people erroneously placed more confidence in the less likely event. This example illustrates a more general phenomenon, namely, over- and underadjustment to the initial anchor. People tend to overestimate the probability of the occurrence of conjunctive events and to underestimate the probability of disjunctive events.

In estimating probabilities involving compound events, decision makers are likely to make systematic errors of the anchoring kind. In judging the likelihood that an enterprise involving a series of interconnected events will succeed, people will tend to overestimate the probability of success. Even if each of the individual events has a high probability of occurrence, the overall probability for the enterprise can be extremely small if the number of elements is large. Intuitive judgments fail to adjust adequately for such conjunctive events. Decision makers estimating subjective likelihoods for the success of business ventures, surgical procedures, technological efforts, or the likelihood that a project will be completed on schedule or at the agreed upon price will be more optimistic about the chances of success than is in fact warranted by reality.

Disjunctive events, by contrast, are commonly encountered in the assessment of risks. Complex systems, such as nuclear reactors or human bodies, will malfunction if any essential component fails.[22] Even if each component has only a very small probability of malfunction, the probability of a system breakdown will be great if the system has many components. Again, intuitive decision makers underadjust departures from the anchor, and underestimate the likelihood of a system failure.

[22] That is why both nature and people build back-up systems or redundancy into their complex creations, to improve the probability of continued function of the system in the face of component breakdowns. As the calculations—and experience—show us, system breakdown is unlikely to be postponed forever. A computable and real margin of failure must exist.

Overconfidence in Judgment

At the beginning of this section, we stated that heuristics often result in erroneous decisions. On other occasions decision heuristics may facilitate proper and efficient decision making. The accuracy of the judgments produced by heuristic processes depends to a great extent on the nature of the question at hand. Accuracy may also depend on how divergent different approaches to the same problem are. This major question—knowing when and under what circumstances these heuristic judgments vitiate decision making or facilitate it—are not completely known and cannot be answered here.

One fact, however, can be unambiguously derived from the extensive literature on the psychology of decision making. People tend to be overconfident in their judgments. Not only do individuals tend to overestimate how much they already know,[23] but they also tend to underestimate how much they have just learned from facts presented in a particular context. Once they do know an outcome, people fail to appreciate how uncertain they were before learning of it.

A number of studies by Baruch Fischhoff and his associates (Fischhoff, 1975; Fischhoff and Beyth, 1975) demonstrate this knew-it-all-along effect. In one experiment, Fischhoff took a number of general knowledge questions from almanacs and encyclopedias. Various groups of people were asked to answer a set of these questions, were given the right answers, and asked to recall what their original answers had been. The findings showed that the subjects overestimated how much they knew initially, and tended to forget their initial errors.[24] Surprisingly, this tendency to overestimate what they knew persisted in the face of attempts to undo the knew-it-all-along effect. Further experiments showed that these overestimation effects were produced even when subjects were exhorted to be as correct as possible in their estimates of how much they did or did not know, or when they were actually told about the bias. Informing people about the tendency toward such judgmental distortions did not serve to eliminate them.

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[23] For an example showing that physicians overestimate what they know and can predict, see Gilbert *et al.*, 1977.

[24] The study was more complicated than our summary of it, including a "memory" group which was asked to answer a set of the questions, told the correct answers, and then asked to recall their own initial responses; a "reliability" group which was asked to answer the questions and then to recall their answers without an intervening step; and a "hypothetical" group which was shown the same group of questions with the answers indicated and asked what their answers would have been had they not been told the answers.

In related studies, Fischhoff found a "hindsight" effect. Evidence was perceived as leading more surely to a conclusion once that conclusion was known. For example, suppose people are given information about the parties and events surrounding an actual military conflict and are asked to predict the outcome and to state the certainty of their prediction. Other people are told the outcome and asked how certain they would have been that that was the outcome had they been given only the input information. People who have been told the outcome are about twice as certain that that would have been the outcome compared to those not told. This occurs even when the "outcome" they are told about is *not in fact the true one*. The input information is perceived as far more predictive of the outcome once the outcome is known than when the outcome is still in doubt.

Essentially, people find it difficult to disregard information that they already possess. Telling people that an event has occurred causes them to report that the event was more likely to have happened. Furthermore, hearing such information does not also cause them to report that the information affected their perceptions or decisions. People do not appreciate the extent to which hearing new information has an effect on their judgments.

Why do people tend to be overconfident in their judgments? One possibility is that individuals reinterpret previous information in light of new information, so that the two sets of information are integrated into a coherent whole. The "old" view of these events is assimilated into the "new" correct view in such a natural and immediate fashion that the assimilator is unaware that his or her perspective has been altered. The outcome psychologically is that the person reports that he or she really knew the answer or held the same opinion previously, and that a discrepancy never existed between initial reactions and the apparent conclusions.

These findings have strong implications for the legal process. Fischhoff's principle may be operating when jurors are presented with evidence that is subsequently ruled inadmissible. Though they may not incorporate the evidence in later decisions, the judgments that preceded the information may be irretrievably altered (Sue *et al.*, 1973; Loftus and Loftus, 1976). Another extension of the phenomenon may go to the heart of some judicial proceedings. Typically, when solving a problem or answering a question, we first get the relevant information and then try to generate a solution or choose from among several alternative solutions. In a criminal trial, people are first given the "answer"—that is, the defendant. Then, the evidence is provided, and the fact finder is asked whether the evidence does in fact prove the conclusion. This arrangement seems especially prone to hindsight. Each of the bits of evidence will appear more likely to lead to the defendant than they would have if the defendant were not already known. Analogizing from the hindsight experiments to the "fact finders" at trial, the evidence will seem to point more surely to the answer than it did when the investigators were developing the evidence. It may be that the high standard of proof required for a finding of guilt makes up for the peculiarity (and consequent distorting effects) of the way the question is posed: answer first. It is noteworthy that only criminal proceedings are framed this way and only criminal proceedings require the highest standard of proof. An interesting alternative procedure might be to experiment with trials in which the evidence is presented first and fact finders are asked which of several defendants, if any, is the guilty party. Under such conditions, fact finders, lacking the judgmental bias produced by hindsight, would probably be less sure of their judgments than is true with the existing criminal trial structure.

III. FURTHER IMPLICATIONS FOR THE TRIAL PROCESS

Differential Accuracy

As society becomes increasingly sophisticated in its use of science and mathematics, statistical and other types of quantitative data will increasingly find their way into court. The entry way may vary—through forensic sciences in criminal proceedings, through civil actions in which substantive technical evidence is relevant (such as we already see in antitrust [Areeda, 1974], products liability [Schreiber, 1967], or employment discrimination [Baldus and Cole, 1979]) or through the increasing number of "science and technology cases" prompted by regulatory agency actions, and in other ways. Through whichever door these data enter the courtroom, once there, humans will have to deal somehow with the relevant information in making their decisions. The fact that humans are heuristic information processors and consequently will make systematic errors in raw intuitive judgment, confronts the courts with challenges to their role as a fact finding agency.

Any solution to this challenge may, however, be an unsatisfying one. As Tribe has argued, the trial is not only a

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search for truth, but also a social ritual which supports certain values and helps litigants and the society as a whole to accept the judgments of courts (Tribe, 1971: 1376). Tribe goes so far as to argue that the more formal mathematical processing departs from intuition, the more it should be eschewed by the courts (1971: 1376). As we have seen, under specifiable circumstances, intuition is a poor guide and may lead to incorrect conclusions. To accept the dilemma posed by Tribe and adopt his preference for intuition is to choose a comforting ritual over accurate decisions, much like a patient who would rather have a human physician make a wrong diagnosis than allow a computer to make a correct one. The discovery of heuristic decision processes sharpens this dilemma by clarifying the costs of truth seeking: the decision maker whose only tool is intuition will often err.

One may be unconvinced of this if we attend only to judicial proceedings, where the criterion of accuracy is permanently elusive. (If some ultimate truth were available against which to test the fact finder's accuracy, there would be little need for the trial.) In many other decision-making contexts, such as where medical diagnoses are testable against later and better evidence, or where psychiatric predictions are testable against future behavior, or where predictions about weather or economic behavior or the performance of physicial materials are testable against easily observable criteria, it is possible to evaluate the intuitive decision maker's accuracy in comparison to other decision-making devices, notably formal decision models. It has been well established for some time now that when the same information is available to intuitive humans or a good mathematical model, the human's decisions are consistently less accurate.[25] These studies have been conducted in a variety of decision-making contexts and we think it safe to generalize these processes to human judgment in legal settings.

We might ask how human decision making differs, if at all, in its processes or products, when contrasted to decision making by mathematical models. That differences exist seems

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[25] This is not to say that computers are always better. But for defined decision-making tasks, they certainly make better "judgments." In the 1940's, when statistical decision models were introduced to aid clinical psychologists, the rationale was to provide a "floor" of statistical accuracy below which the clinical diagnostician could not fall. But, the floor turned out to be a "ceiling." The intuitive diagnosis could not reach above it. See Dawes and Corrigan, 1974; Goldberg, 1970; Meehl, 1954.

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universally accepted.[26] Even when mathematical tools are modeled after human decision processes, the copy works better than the original. One can "capture the decision policies" of individuals, converting their choice behavior into a mathematical statement which links the input evidence to the decision.[27] This "paramorphic linear representation" of the human decision maker can be directly compared with the individual's judgments. Consistently, the paramorphic linear representation of the human decision maker is more accurate than the decision maker, a phenomenon known as "bootstrapping" (Dawes and Corrigan, 1974: 101). Even then, models using random weights do better than both the human or the human's model (Dawes and Corrigan, 1974: 102). One learns a few things about human information processing from such comparisons. The mathematical model of a person's own decision policies is more accurate than the person because it consistently applies the same logic, while the human decision maker fluctuates, being over-influenced by fortuitous, attention-catching pieces of information that vary from time to time, and processing a too-limited set of variables.[28] Unaided individuals tend to have great difficulty incorporating quantified variables, give excessive weight to bits and pieces that happen for whatever reason to be salient, base their decisions on less information (often the less useful information) than do mathematical models, and apply their decision policies inconsistently (Dawes and Corrigan, 1974). This presents an interesting set of concerns about human decision making that contrasts with Tribe's concerns about mathematical decision making. The problems associated with drawing inferences from probability evidence, problems Tribe would like to see the courts avoid, are not avoided by dumping the data, quantitative as well as nonquantitative, into the mental laps of human decision makers, armed only with their intuition.

Moreover, the choice is not really between computers and people. It is between explicitly presented computing and subjective computing, or between more and less accurate

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[26] Critics of explicit computation urge us to reject mathematical tools because they can point to flaws. They fail to ask the question "compared to what?" Compared to perfection, these tools do leave something to be desired. Compared to intuitive decision-making, they look better.

[27] One of the first to suggest doing this was Henry Wallace, before becoming vice president under Roosevelt (Wallace, 1923).

[28] See Bowman, 1963. For example, suppose a physician applying a correct decision rule has observed a poor outcome in the last several patients. The physician may, consequently, modify the decision rule in the next several patients. That idiosyncratic fluctuation will reduce accuracy. The "bootstrapped" model will inexorably play the best odds and minimize error.

computing. This is not to degrade humans. It is merely to recognize, on the one hand, our information processing limitations and, on the other, our capacity to invent tools that can do the job better.[29] After all, many people trust their pocket calculators and the light meters in their cameras, whose workings they do not begin to comprehend; yet their faith is well placed, because these devices make decisions and judgments faster and more accurately than people do.[30] The comparison is not between humans and mathematics, but between humans deciding alone and humans deciding with the help of a tool. (See review of person/machine systems in Slovic *et al.*, 1977: 25; also see Saks, 1976.)

Our suggestion is modest, and most lawyers should find it comfortingly traditional. Namely, experts ought to be permitted to offer their data, their algorithms, and their Bayesian theorems. The errors that may be introduced will be subjected to adversarial cross-examination. Various formal mathematical models do have room for errors—variables omitted, poor measurements, and others that Tribe has cogently presented. But so do intuitive techniques. Properly employed and developed, the former can have fewer. It is up to opposing counsel to unmask the errors. Moreover, as a matter of developing and introducing new tools from what might be called decision-making technology, the identification of flaws does not imply that the tools ought not be used. The proper question is whether the tool, however imperfect, still aids the decision maker more than no tool at all.

Under-Incorporating Statistical Information

Another contribution of behavioral decision research to this debate is the challenge it poses to what seems to be a unanimous assumption held both by advocates and opponents of the introduction of mathematical and statistical data and tools to the judicial fact-finding process. This widespread assumption is that the tools and the numbers they produce are unduly persuasive (Tribe, 1971: 1334, 1376). Upon hearing the

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[29] That people can invent tools that do a better job than the humans who invented them should come as no surprise to people who have used such devices as radios, light meters, or hammers. Indeed, the adversary process is just such a tool. It seems intuitively wrong to many people, but it is capable of accomplishing certain purposes that intuitive individuals cannot. See Thibaut and Walker, 1975.

[30] Trust in the pocket calculator is based on experience with it. People who acquire experience with mathematical decision making in management, operations, planning, science, economics, and so on, develop a similar trust in these other computational aids.

technical pronouncement, it is said, fact finders doubt their intuition and more or less blindly accept the conclusions given them.

Research demonstrates, however, that people do not process probabilistic information well, that in the face of particularistic information, they cannot integrate the statistical and anecdotal evidence and consequently tend to ignore the *statistical* information. Intuitive, heuristic, human decision makers must dispense with certain information, and that tends strongly to be the quantitative information. While commentators' arguments have been that the data are inordinately persuasive, the evidence says that the reverse is true. The implications are several. First, statistical data need not be regarded as so overwhelming as some have supposed, and therefore they ought not to be considered prejudicial. The more realistic problem is presenting statistical evidence so that people will incorporate it into their decisions at all.

Aggregate Probabilities

A third and related implication has to do with the role of aggregate probabilities (base rates) in making decisions in a specific case. The problem usually posed is: how can information about a general state of affairs, background information, legislative facts, base rates, serve as evidence about a specific event? Several examples may help to clarify the question (drawn from Tribe, 1971):

1) A person is found guilty of heroin possession. The next question is whether the drug was domestic or illegally imported. It can be shown that 98 percent of all illegally possessed heroin is illegally imported. May this fact be used in deciding the question in this case?

(2) A physician sued for malpractice is accused of having dispensed a drug without warning of what he knew to be its tendency to cause blindness in pregnant women. Should he be allowed to introduce evidence that 95 percent of all physicians are unaware of that side effect (as evidence that he did not know)?

(3) A plaintiff is negligently run down by a blue bus. The question is whether the blue bus belonged to the defendant who, it can be shown, owns 85 percent of the blue buses in town. What effect may such evidence be permitted to have?

We know from the research described earlier that when a decision involves only simple base-rate data, people make (approximately) the correct probability estimate. The legal question is whether such evidence may be offered as proof. The argument for admitting it rests largely on the contribution such evidence will make to reaching a correct finding based on available information. The argument against it rests on the premise that base rates are uninformative about specific cases.[31] "[I]t has been held not enough that mathematically the chances somewhat favor a proposition to be proved; for example, the fact that colored automobiles made in the current year outnumber black ones would not warrant a finding that an undescribed automobile of the current year is colored and not black, nor would the fact that only a minority of men die of cancer warrant a finding that a particular man did not die of cancer" (*Sargent* v. *Massachusetts Accident Co.*, 1940). [Such cases] are entirely sensible if understood . . . as insisting on the presentation of *some* non-statistical and 'individualized' proof of identity before compelling a party to pay damages, and even before compelling him to come forward with defensive evidence, absent an adequate explanation of the failure to present such individualized proof" (Tribe, 1971: 1344 n.37).

The assumption in these decisions is that somehow particularistic evidence is of greater probative value, that is, is more diagnostic. The studies we have described can be seen as making some enlightening points about such a seeming distinction. If neither case-specific nor base-rate data are available, the fact finder has no real way to evaluate a witness's statement. In the absence of internal or external contradiction, they probably accept it as credible. When only case-specific information is present, the fact finder regards the probability that proposition X is true as equal to the credibility of the witness. This is a condition which exists *only* when the base rate is 50:50.[32] If no base-rate data are available, and this is common, the fact finders are doing the best they can; in essence, placing an even bet.

Now consider what is gained when base-rate information is added. The value of the base-rate information is that it provides a context in which the case-specific information has meaning. Once one knows that 85 percent of the buses are blue, and that the witness is 80 percent accurate in the

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[31] Poor use of statistics and probability theory is beside the point. As Tribe points out, the possible costs of correct use are the issue.

[32] *Cf.*, medical laboratory testing example, supra note 5. By ignoring the base rate or by refusing to admit it into evidence, the decision maker substitutes a false base rate (50:50) for the correct one and necessarily reaches a distorted conclusion.

appropriate color identification task, then one can, with the proper tools, evaluate the probative force of the statement "I saw the bus, and it was blue."[33] Contrary to the speculations of many commentators, the research on heuristics suggests that errors are massively in the direction of being seduced by case-specific information and failing to employ base-rate information to temper belief in a witness's credibility.[34]

The Myth of Particularistic Proof

Perhaps the most serious error is an epistemological one: the assumption that case-specific information is really *qualitatively* different from base-rate information. The courts, commentators, and we through most of this article have categorized them separately. And, indeed, it seems obvious that background base-rate information is about other cases while particularistic information is about *this* case. Whatever meaning the distinction may have, it is not one that pertains to the probability of an accurate decision on the facts. Much of the testimony that is commonly thought of as particularistic only seems so. It is far more probabilistic than we normally allow jurors (or judges) to realize. This includes eyewitness identification (e.g., Buckhout, 1974; Gardner, 1933; Munsterberg, 1976; Levine and Tapp 1973), fingerprints (Galton 1965), and anything else we could name. This follows not from the nature (and fallibility) of these particular techniques, but from the nature of the logic of classifying and identifying. All identification techniques place the identified object in a class with others (Tribe, 1971: 1330 n.2). There is little, if any, pin-pointed, one-person-only evidence in this world. In fairness to Tribe, he notes this non-distinction, then promptly ignores its implications by saying, "I am, of course, aware that *all* factual evidence is ultimately statistical, and all legal proof ultimately probabilistic, in the epistemological sense that no conclusion can ever be drawn from empirical data without some step of inductive inference—even if only an inference that things are usually what they are perceived to be. . . . My concern, however, is only with types of evidence and modes of proof that bring this 'probabilistic' element of inference to explicit attention in a quantified way. As I hope to show, much turns

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33 If 95 percent of the buses are blue, and the witness is 80 percent accurate, when a witness reports seeing a blue bus, this yields a .98 probability that the bus was, indeed, blue.

34 Our experts on eyewitness accuracy, supra, have been trying to do just this tempering. Unfortunately, as we have seen, their base rates tend to be ignored.

on whether such explicit quantification is attempted" (Tribe, 1971: 1330 n.2). The problems of probability do not come into existence only when we become aware of them. Making them explicit does not create the problems, it only forces us to recognize them and enables us to begin dealing with them. Burying them in implicitness is no solution; revealing their existence is not the problem.

Suppose we must decide if a person on trial for possession of heroin is guilty also of possessing illegally imported heroin. And suppose we can learn either that 90 percent of all heroin in the U.S. is illegally imported or that a witness whom we judge to be 80 percent credible (e.g., knows and tells the truth 80 percent of the time) asserts that he (or she) observed the delivery and it was an illegal importation.

The usual argument, recall, is that the particularistic evidence tells us something on which we can base a decision, while the base-rate data are all but irrelevant to the case at hand. But, from the viewpoint of a disinterested fact finder, all information is indirect, distant, abstract, and imperfectly credible. The fact finders, in terms of their truth-seeking role, simply have a set of input information on which to base a judgment, and depending on the characteristics of the evidence and the way it is processed, that finding will have a greater or lesser probability of being correct. The simple fact in this example is that the fact finder can be 80 percent sure of being right or 90 percent sure. Consequently, in this instance it is the base-rate information that is more diagnostic, more probative, and more likely to lead to a correct conclusion.

Making this argument with the relatively concrete images of a case hampers our consideration of the concept. Let us try to make the point with one of those concretely abstract statistical anecdotes. Suppose you are at a state fair and approach a kind of shell game. You are presented with two overturned cups, each hiding a marble. One of the marbles is red. Your task is to bet on which cup is covering the red marble. You learn that under one cup is a marble drawn randomly from a bag containing 90 percent red marbles. A bystander, whom you know to tell the truth 80 percent of the time tells you, "I saw the marble placed under the other cup, and it was red." Placing your bet, the base-rate vs. case-specific character of the evidence is irrelevant. The odds of betting correctly, of maximizing the likelihood of winning, are dictated only by the content of the information. The question for the decision maker is which is more informative, an imperfectly credible witness, or an imperfectly pinpointed set of base-rate information. One choice offers a .90 probability of being correct, the other only .80. The diagnostic value of the information is not affected by whether it appears to report background facts or "case-specific" facts. Even so-called particularistic evidence is probabilistic. Invariably, all information is really probability information. Only if we neglect to uncover, or otherwise conceal from a fact finder the base rates of witness (or other evidence) reliability, will the case-specific information seem more informative. Only if we conceal from the bettor the fact that the witness who says "I saw the marble and it was red" is only .80 truthful or .50 accurate in color perception, will the assertion seem to have special probative force. The distinction between what one can learn from case-specific as opposed to base-rate information is more imaginary than real. In terms of accurate fact finding, it is a difference that makes no difference.

Similarly mistaken are distinctions between certain kinds of identifications. Descriptions which lead to a probability of correct classification of a person (e.g., "a completely bald man with a wooden left leg, wearing a black patch over his right eye and bearing a six-inch scar under his left, who flees from the scene of the crime in a chartreuse Thunderbird with two dented fenders") are treated as different from the "particularistic" type where a witness says, "Yes, that's the person." Some have argued that evidence that the above description fits only one person in 64 million ought not to be used in the trial of a person fitting that description, because it merely specifies the class to which he belongs and its size; it does not identify him. The latter identification would be more welcome, because it singles out a unique individual. The identifying witness may be confident that the identification is correct, but the fact finder ought to appreciate the inherently probabilistic nature of perception, storage, recall, and identification. Apparently, fact finders (like legal commentators) fail to appreciate this point. They act as though the eyewitness identification is highly accurate, when in reality it may be far more likely than once in 64 million to be in error. Indeed, the probability of correct eyewitness identification has been found to be far lower than commonly assumed (Buckout, 1974; Loftus, 1980).

The most meaningful difference between these two kinds of identification is that in one we allow the identifying witness to make the decision instead of letting the fact finder do so.

But to think we have here evidence that is somehow uniquely diagnostic is only to conceal from ourselves the probabilistic nature and limited accuracy of the identification process.[35] In *both kinds* of identifications we are dealing with classes containing more than one person, and there is no guarantee that the "particularistic" approach yields smaller classes.

By disposing of the false distinction between probabilistic and particularistic evidence, we also obviate the interesting worry that probability evidence cannot support a finding of liability or guilt in the way that particularistic evidence can, by virtue of the latter's ability to pinpoint. To the extent that the goal of adjudication includes accuracy, the background data are not without probative force. Like it or not, base-rate information can be helpful to a decision maker. We may for other reasons lament this state of affairs, but it remains a fact of life in making decisions under uncertainty.

Evaluating Witness Credibility

Probability evidence can address quite usefully the credibility of a witness. Such data are probably most available and most useful in this sphere—informing about the witness more so than about the defendant. As we saw earlier, heuristic decision makers tend to equate the probability that a conclusion is correct with the credibility of a witness. Consider two examples of how such background data can inform a fact finder about the reliability and validity of a witness's testimony.

1. A forensic scientist testifies that a paint sample matches the defendant's automobile, a blood stain on the upholstery matches that of the victim, and the fatal bullet was fired from the defendant's gun. Such scientific evidence is often highly credible testimony. Most critics of probability evidence would be pleased that it is particularistic; it pinpoints the defendant (or at least the defendant's property); it does not merely define a class to which the defendant belongs. First of all, as we have argued, particularistic evidence is nothing of the sort. This expert's evidence, like all evidence, rests on a foundation of reality that is necessarily probabilistic. The same or another expert could testify as to the probability of an

[35] This parallels the concern that a statistician using Bayes' Theorem to reach a probability of guilt determination is making the decision for the fact finder. If we have eyewitnesses, let us also have appropriate experts to offset the eyewitness's inordinate impact.

accurate identification—that is, the size of the class to which the defendant's car's paint, the victim's blood, and the defendant's gun belong, relative to the respective universes of paint, blood, and firearms. Or the expert could testify to the joint probability of all three occurring. Furthermore, this or another expert could testify to the probability that the paint, blood, and ballistics really do match, given that the test for a match was positive. And although the expert may be confident of the conclusions testified to, this or another expert could inform the court about relevant background findings such as those of the Forensic Sciences Association in a national study (Peterson *et al.*, 1978) showing that as many as 51 percent of police laboratories misidentified paint samples, 71 percent misidentified blood samples, and 28 percent misidentified firearms. None of these is what we might call a pinpoint of accuracy. In such light, the testimony takes on a different appearance.

2. In appropriate circumstances it would be informative to a fact finder to be advised of the diagnostic error rates of physicians or of the laboratory tests on which they often base their diagnoses. Virtually every medical test has an error rate. Virtually every test has a known specificity (the percentage of negative results among people who do not have the disease—that is, the true negatives), and this value is not uncommonly 80 percent or lower. Similarly, virtually every test has a known sensitivity (the percentage of positive results among people who do have the disease—that is, the true positives), and this value is not uncommonly 70 percent or lower.[36] Add to this any evidence of additional error due to laboratory inaccuracy (that is, errors over and above those inherent in the test, available from quality control studies), and the fact finder may have a quantitative sense of how many grains of salt to include when weighing such expert testimony.

All testimony, including eyewitness accounts as well as such expert testimony, may be tempered by the introduction of relevant background base-rate probabilities. It is noteworthy that these error rates and base-rate probabilities, these ubiquitous limiting features of all evidence, not only recognized but also *measured* by every

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[36] What has been said here is true of *all* test instruments, including judges and juries. *Cf.* Krieg *et al.*, 1974.

scientific discipline, are often simply ignored by legal commentators on the use of such evidence in court.

IV. CONCLUSION

Tribe advocates, in short, the maintenance of a fantasyland of apparent certainty in a world of patent uncertainty. Regarded from only a mildly different angle, such a deliberate turning away from reality may serve neither the law nor the defendant. First of all, the symbolism is so at variance with the objective reality as well as with the conceptualizations of legal scholars (certainly including Tribe himself) and the subjective experience of judges and jurors, that this may be one more of the legal fictions that tend to undermine the law's own credibility. An institution that would so deliberately ignore real, measurable doubt and assert not that it has made the best decision it was able to but that it is "certain" it is correct, is unlikely to keep the masquerade going forever or to fool everyone. That is the harm that may be done the court.[37]

The harm that may be done a defendant is that behind this mask of certainty can hide not only minute quantities of uncertainty, but *massive* quantities. Relevant evidence might be weak indeed, but so long as it is kept fuzzy, a finding against a defendant could be rendered and claimed to be certain. Is this an affirmation of the accused's dignity?

Candid announcement of unavoidable margins of error may be a greater service to individual defendants and to the legal system. With such awareness we may be motivated to modify one of our most important social inventions to make it work better (err less); we may recognize that truth is not merely anything that a court asserts it to be; and both legal policy makers and case-by-case fact finders will not be able to hide from the implications and consequences of their own decisions nor from the context in which they must decide.

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[37] One major survey of the low esteem in which the public holds the courts is Yankelovich *et al.*, 1978.

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