

Experimental Research on Jury Decision-Making

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Because trial juries deliberate in secrecy, legal debates about jury functioning have relied heavily on anecdote and speculation. In recent years, investigators have begun to challenge many common assumptions about jury behavior. An important tool in this effort has been the mock jury experiment, in which research participants are randomly assigned to alternative trial conditions and asked to reach a verdict in a simulated case. Researchers have used mock jury experiments to test hypotheses about causal influences on jury behavior and to develop theoretical models of the jury deliberation process.

JURY VERDICTS DIRECTLY AFFECT THE LIVES OF HUNDREDS OF thousands of individuals in the United States every year and serve a broader bellwether function in plea bargaining and settlement negotiations (1). But because jury deliberation is cloaked in secrecy, legal policy-makers have made important decisions about the scope and conduct of jury trials on the basis of untested intuitions about how juries reach their verdicts (2, 3). In this review of research on jury behavior, I will emphasize the use of mock jury experiments to test hypotheses and refine theoretical models of the decision process. Because jury decision-making involves two different phases—cognitive processing during the trial and deliberation in the jury room—I review research on both the trial and deliberation phases of the judgment process. In keeping with the emphasis of most jury research, I focus primarily on decision-making in criminal trials; the extent to which these findings generalize to civil litigation is not clear (3).

Jury Research Methods

In the 1950s, researchers at the University of Chicago covertly recorded the deliberations of several federal juries. Despite the court's cooperation, this endeavor was aborted by a congressional inquiry, resulting in legislation prohibiting attempts to observe or record jury deliberation (4). Since then, researchers have resorted to other strategies to study jury behavior, most notably archival analyses and mock jury experiments. In the archival approach, jury verdicts are sampled from court records or court reporting services and analyzed statistically to describe longitudinal trends and to identify relations between verdicts and case characteristics (5). But archival data sources omit a great deal of potentially relevant information and only document what juries have done, not how or why they did it. Researchers must attempt to infer the latter, which is precarious because one can never completely disentangle the natural covariation among various case and trial characteristics.

In order to better understand the jury decision-making process,

researchers would like controlled experiments with random assignment to conditions under study. In some instances, courts have randomly assigned jury trials to alternative procedures, but manipulations of many variables of interest are not ethically or legally feasible in actual trial settings (6). Mock juries must be used for most experiments; in these, research participants are asked to reach judgments regarding a simulated legal trial. The mock jury approach has the added advantage of permitting replication across juries within the context of a single trial, and there is no legal barrier to observing deliberation (7).

Differences between these experiments and actual trials have led some observers to question whether generalizable conclusions about actual jury behavior can be reached by studying the behavior of mock juries reacting to written, audiotaped, or videotaped trial reenactments (8). The effects of several factors that distinguish mock jury simulations from actual trials have been assessed empirically. Experiments comparing mock jurors with subjects who thought they were actually trying a case have been inconclusive; different studies have found mock jurors' verdicts to be more lenient, less lenient, and no different from those of "actual" jurors (9). Other studies have examined the effects of the frequent use of college students as mock jurors, finding little or no difference in comparisons of verdicts by student and adult jury-eligible respondents for the same cases (10, 11). There is some evidence that simulated trial presentations might artificially exaggerate the impact of experimentally manipulated variables, particularly defendant characteristics (12). But mock jurors do not appear to reach decisions by a fundamentally different process than actual jurors (8, 13). When the objective is to precisely estimate the magnitude of relations among variables in actual jury trials, the archival method is more appropriate. The role of mock jury experimentation is to explain the processes underlying those relations.

Predeliberation Juror Judgment

Evidence evaluation at trial. One of the earliest findings in mock jury research was that despite judges' instructions to the contrary, many jurors form tentative verdict preferences early in the trial (14), a finding that underscores the importance of studying predeliberation juror judgment as an adjunct to research on jury deliberation. Rather than cataloging the dozens of trial and case characteristics that have been found to influence jurors, I will briefly review several theoretical models of individual juror judgment that have proved useful for stimulating research on general principles of juror judgment (15).

The Bayesian and information integration models each represent a juror's evaluation of the evidence as a unidimensional subjective probability judgment. These models are framed in mathematical

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terms, but theorists are not proposing that jurors literally carry out such calculations in their heads: "now I'll divide by 0.5 and carry the 1." Instead, the formulas are a useful way of explicitly predicting the functional relations among a juror's assessment of each evidentiary item and his or her overall judgment. In the simplest Bayesian model (15), the juror's estimate of the odds of guilt given n items of trial evidence is $R_n = R_0(L_1)(L_2) \dots (L_n)$, where $R_0 = P(G|e_0)/P(NG|e_0)$, which represents the juror's initial odds estimate of the defendant's being guilty (G) or not guilty (NG) given the fact that the defendant is on trial (e_0), and $L_i = P(e_i|G)/P(e_i|NG)$, a likelihood ratio representing the perceived diagnosticity of item e_i . More sophisticated versions use complex hierarchical chains of inference to account for dependencies among evidentiary items (16). Arguably, Bayesian models depict how a "rational" person would aggregate the evidence, but they generally do a poor job of describing juror judgment (15). For example, relative to Bayesian norms, mock jurors do not adequately adjust their judgments to take into account forensic incidence statistics presented in expert testimony—for instance, the likelihood that the offender and the defendant would have matching hair samples by chance (17). Also, mock jurors have been found to "double count" redundant testimony from corroborative witnesses (16).

The information integration model of juror judgment is grounded in basic research on human judgment (18). According to this model, a juror's evaluation of the evidence, J , can be described by a weighted average of the pretrial opinion, s_0 , and the subjective probability of guilt or liability implied by each evidentiary item, s_i . Thus, $J = (w_0s_0 + \sum w_i s_i)/(w_0 + \sum w_i)$, where w_0 and w_i refer to the weight given to the pretrial opinion and the i th evidentiary item, respectively (15, 19). These weights are postulated to reflect each item's perceived relevance and credibility. Psychologically, this model can be characterized as a process in which the juror's global judgment is continually adjusted so as to fall between its previous value and the value of each new piece of evidence that is presented at trial (20). Mock juror research findings are generally consistent with this averaging model (19), although rigorous tests are rare (15). This model can account for the underuse of incidence statistics and other forms of base-rate evidence; they are simply "averaged in" along with other less statistically reliable items of evidence (20). The model can also explain the impact of redundant testimony; by attenuating the contribution of the pretrial opinion, two items with the same value can produce a more extreme judgment than either one alone (18).

The Bayesian and information integration models represent the juror's judgment on a continuous scale, but jurors are typically required to reach a categorical verdict. Thus, the juror's judgment must be compared to a decision threshold, which should ideally correspond to the assigned standard of proof; for example, the criminal "reasonable doubt" standard. But because legal definitions of these standards are ambiguous, there is considerable variance in the thresholds jurors actually adopt (21, 22). Several theorists (23) have suggested a decision-theory derivation of the juror's threshold. Given the perceived probability of guilt, p , and the expected regret over convicting an innocent defendant, D_{ci} , or acquitting a guilty defendant, D_{ag} , the juror can minimize his or her expected regret by setting a threshold value of $p^* = D_{ci}/(D_{ci} + D_{ag})$. With this model, it is possible to predict jurors' verdicts about 80% of the time by matching their probability-of-guilt ratings to the value of p^* estimated from their expected regret ratings (21, 22). This is a better than chance rate, although it suggests that better models are needed.

The recent "story" model (13, 15, 24) of juror cognition departs from these unidimensional approaches. The model is an extension of basic research on the cognitive representation of narrative information. According to this model, jurors use episode schemata—generic

knowledge structures abstracted from prior experience—to remember and organize trial evidence into a plausible story. Jurors then attempt to match the story to available verdict categories, selecting the verdict that provides the best fit. The story model is a psychologically plausible account of juror decisionmaking, and it is the only model in which serious consideration is given to the role of memory processes during the trial, but more research is needed to establish its predictive validity and heuristic value for generating testable hypotheses.

Juror biases. Intuition and courtroom folklore suggest that jurors' personal characteristics might predispose them toward certain verdicts. Attorneys attempt to detect these predispositions during jury selection proceedings, traditionally relying on hunches and stereotypical rules of thumb. In recent years, some defense lawyers have hired social scientists to conduct "scientific jury selection," which usually involves a survey of community knowledge and attitudes regarding the issues in dispute, occasionally supplemented by clinical observation of potential jurors under questioning (25). The relation of survey items intended to serve as a proxy for verdict preference with various demographic, personality, and attitudinal variables is evaluated by regression analysis in order to build a statistical profile of the client's ideal juror.

However, a large body of empirical research calls into question the premise that jurors' votes during deliberation can be reliably predicted from juror characteristics that are observable before trial. In general, jurors' demographic attributes, personality traits, and general attitudes are associated weakly and unreliably with jurors' verdicts (1, 13, 26). For example, in a study of over 800 mock jurors recruited from Boston-area jury pools, jurors' education, occupation, political ideology, gender, age, and trial experience collectively accounted for less than 2% of the variance in their verdict preferences (13). But proponents of scientific jury selection argue that the approach is most effective in trials involving controversial issues. Capital punishment might be one such issue; numerous studies have found that attitudes toward the death penalty in the abstract reliably predict the decision to vote to convict a defendant accused of homicide (27).

A more robust source of bias in juror judgment results from exposure to extralegal information. Studies have documented reliable effects of pretrial publicity, inadmissible evidence, and litigants' physical characteristics on mock juror judgments (1, 28, 29). When seemingly probative information is ruled inadmissible because of due process violations, jurors may nevertheless incorporate it in their probability-of-guilt assessment (29). But other extralegal factors, such as the attractiveness of an automobile theft victim, appear to influence verdicts indirectly by heightening the anticipated regret of either convicting the innocent or acquitting the guilty and thereby raising or lowering jurors' standard-of-proof thresholds (30).

The Deliberation Process

Charting factional movement in the jury. In the 1960s, Kalven and Zeisel (31) used post-trial juror interviews to reconstruct the initial ballots in 225 criminal jury deliberations. Of the 146 juries with a nonunanimous majority at first ballot, only seven reached the verdict advocated by the minority faction. Kalven and Zeisel suggested that "with very few exceptions the first ballot decides the outcome of the verdict. . . . The deliberation process might well be likened to what the developer does for an exposed film; it brings out the picture, but the outcome is predetermined" (31, pp. 488–489).

In the years since Kalven and Zeisel's analysis, a number of stochastic models of jury decision-making have been developed (32), some of which have been implemented as computer simulations (13,

33). A common feature of these models is the use of the group state—the distribution of jurors across distinct verdict factions—as the unit of analysis. For example, an 8:4 state would indicate that 8 jurors favor conviction and 4 jurors favor acquittal in a 12-person jury. These models make a number of assumptions about the dynamics of jury deliberation that have been assessed empirically.

Following Kalven and Zeisel (31), each model has as an assumption that a faction's influence is a function of its relative size. This majority effect is easily the most robust finding in mock jury research (13, 32). Even when a jury is ostensibly operating under a unanimity decision rule, its verdict can be predicted fairly reliably by an implicit two-thirds majority rule. A related phenomenon, group polarization, has been documented in mock jury research and in hundreds of other small group laboratory studies (19, 34). To the extent that a group's average predeliberation opinion deviates from the neutral point on a bipolar scale, the average postdeliberation opinion will tend to be more extreme in the same direction. All other things being equal, polarization does not occur when equal sized and equally opinionated factions are opposed.

However, in criminal juries, all other things are not equal. One might expect influence to be symmetrical within equal-split group states (for example, 6:6) or between equal-ratio group states (for example, 8:4 with 4:8). If so, each faction in a 6:6 group would be equally likely to win, and a two-thirds majority would be as likely to win no matter which verdict it favored. Nevertheless, there is considerable evidence that factions favoring acquittal have more influence than factions of equivalent size favoring conviction (11, 32). This asymmetry effect appears to be a consequence of the asymmetric reasonable doubt standard used in criminal trials. In a recent experiment (11), the asymmetry effect was reproduced when mock juries were assigned the reasonable doubt standard, but influence was symmetrical in mock juries that tried the same criminal case under the symmetrical "preponderance of evidence" standard used in civil litigation. The reasonable doubt standard appears to provide a rhetorical advantage for advocates of acquittal during deliberation, and the effect of the standard is thereby amplified by group discussion.

A common modeling assumption is that influence is proportional to the relative size of a faction, but not its absolute size: for example, that 8:4, 4:2, and 2:1 are functionally equivalent group states. In *Williams v. Florida* (2), the Supreme Court explicitly adopted this proportionality assumption in its decision to uphold the use of 6-person criminal juries in state courts. In an experimental comparison of 12-, 6-, and 3-person mock juries, two different violations of proportionality were observed, both of which agree with replicate basic results in conformity research (35). First, there was more majority influence in the 2:1 state than in the 4:2 or 8:4 states; that is, lone minorities fared more poorly than their proportional counterparts. Second, a minority-of-one was less likely to yield to a 2-person majority than to a 5- or 11-person majority. Nevertheless, the proportionality assumption held up well in comparisons of 6- and 12-person juries, which encompasses the existing range of permissible jury sizes in the state and federal courts.

The transition among group states during jury deliberation can be modeled as a discrete-state Markov process (33, 36) under the assumption that the process is both stationary and path-independent. Minor violations of each assumption have been found in mock jury research. The process would be stationary if the probability of a given transition between group states remained constant throughout the deliberation process, but stronger majority and asymmetry effects have been found during the second half of deliberation (36). The process would be path-independent if the likelihood of a transition between states was independent of the group's history of previous transitions, but there is correlational evidence for a mo-

mentum-like effect in which a jury's next transition can be predicted by the direction of its previous transition (36). Nevertheless, the violations of these assumptions are of relatively small magnitude, and Markov process models have been fairly successful at predicting mock jury behavior (13, 33).

Sources of influence. By comparing the deliberation process to the development of a photograph, Kalven and Zeisel (31) implied that jury deliberation might be a mere vote-counting formality. This is an exaggeration. The strength-in-numbers effect of the majority involves two different sources of influence: normative influence, the conformity pressures brought to bear on a minority faction, and informational influence, the number and persuasiveness of arguments generated to support a position (34). In content analyses of deliberation, both types of influence are found and both are correlated with mock jurors' final votes (37). Although a faction's size and its ability to generate arguments are naturally confounded, experiments in which one source of influence is held constant while the other is manipulated indicate that both sources affect voting patterns (34).

Informational influence during deliberation is desirable to the extent that it fosters more complete and accurate recall of trial evidence and corrects errors and biases. Ideally, P_j , the probability that the jury will recall an item of evidence, should equal $1 - (1 - P_j)^n$, where P_j is the probability that an individual will recall it and n is the group's size, but actual group recall tends to fall somewhere between this model and a "majority rule" model—that is, social support is often needed to convince others that a recollection is correct (38). Content analyses of deliberation indicate that in some instances jurors admonish each other to ignore inadmissible evidence (29), but information integration theorists (19) have argued that even without such admonishments, the recollection and discussion of trial evidence should reduce the relative weight given to extralegal biases. Although studies in which imbalanced trial evidence is used show that deliberation attenuates biases (19), studies with very close cases show sustained or even enhanced bias after deliberation (22, 39). Kalven and Zeisel (31) suggested that close cases might "liberate" jurors from the evidence and allow their personal sentiments to influence their judgment.

Effects of Structural Task Variables

During the 1970s, a number of controversial Supreme Court decisions relaxed the traditional requirement that a jury consist of 12 members operating under a unanimous decision rule (2). In doing so, the Supreme Court explicitly assumed that within certain limits, a jury's size and decision rule would not influence its functioning. Since then, a considerable body of research on the effects of these variables has accumulated, much of it too late to dissuade the Supreme Court. Neither of these variables systematically affects verdicts in carefully controlled mock jury experiments, but smaller and nonunanimous juries recall less evidence, deliberate more quickly and less thoroughly, and are more likely to reach a verdict than their traditional counterparts (13, 35). Moreover, rudimentary sampling theory indicates that a smaller jury will be less representative of minority viewpoints in the community, and mathematical simulations suggest that smaller and nonunanimous juries might be more likely to falsely convict the innocent or acquit the guilty (32). Whether these structural changes have increased trial efficiency enough to offset potentially deleterious effects on the performance and perceived legitimacy of the jury remains an issue for public debate (40).

Jury researchers have devoted the most attention to cases in which a jury must render a dichotomous criminal verdict, guilty or not

guilty. Several studies suggest that the availability of multiple response options can fundamentally alter the jury's decision. For example, providing mock jurors with a guilty-but-mentally-ill option results in a significant reduction in not guilty by reason of insanity verdicts in insanity defense cases (41), and there are similar response option effects in homicide cases (42). Juries are occasionally asked to reach multiple verdicts, as when criminal defendants are tried for multiple offenses involving separate incidents. A number of experiments have shown that mock jurors are more likely to convict a defendant of a given charge in a joined trial than when the same charge is tried separately (43).

Because jury research has focused almost exclusively on criminal cases, relatively little is known about how juries allocate civil liability among parties and assess compensatory and punitive damages, continuous judgments that might evoke very different decision processes. This is unfortunate because there is currently an active legal debate about the jury's role in resolving product liability, medical malpractice, and other civil disputes. There is also a growing use of special interrogatories and itemized verdicts, which require jurors to disaggregate complex decisions. These topics are ripe for theoretical development and research (3).

Conclusions

Empirical research on jury functioning is gradually replacing the reliance on anecdotes and speculation in the legal policy domain. Much is now known about cognitive processing at trial and the dynamics of jury deliberation, and the effects of many key trial variables are generally understood. But in an evaluation of the jury's merit as a legal institution many dimensions must be considered—judgmental thoroughness and accuracy, legal competence, impartiality, representativeness, consistency, efficiency, and perceived legitimacy—only some of which can be assessed by mock jury research (40). Although it can be readily shown that jury performance falls short of ideal standards on some of these dimensions, the critical questions for public policy are (i) under what conditions can jury performance be enhanced, and (ii) how does the jury perform relative to other legal decision-makers?

Researchers have begun to address the first question, but less is known about the second one. In a survey of more than 3500 criminal jury trials conducted in the 1950s (31), the judge agreed with the jury's verdict more than 75% of the time, but the sources of the judge-jury disagreements are still not understood. It is not clear whether these disagreements indicate that judges and jurors evaluate testimony differently or apply different standards of proof, or whether judges and juries follow completely different judgment processes. Experimental trial simulations that compare the processes by which juries, professional trial judges, and other legal fact finders reach their verdicts may provide answers to this question.

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The Heliosphere as an Astrophysical Laboratory for Particle Acceleration

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Particle acceleration is one of the most important topics in plasma astrophysics as well as in cosmic-ray astrophysics. The heliosphere is an ideal astrophysical laboratory, wherein one can observe in situ the elementary mechanisms involved in the particle acceleration processes. Two phenomena of special interest are stochastic acceleration in the magnetohydrodynamic turbulence around comets and stochastic shock acceleration at interplanetary shock waves.

IN DILUTE PLASMAS IN THE UNIVERSE, THE USUAL TWO-BODY Coulomb collisions are relatively unimportant and the behavior of charged particles is governed by collective interactions through long-range electromagnetic forces. When some dynamical energy release occurs in these plasmas, a part of the thermal population is accelerated to high energies, so that the particle distribution deviates significantly from the Maxwell-Boltzmann distribution. By studying the particle acceleration process, we can understand the detailed physics of the energy conversion process and recognize what extreme conditions are attained by particles in the system.

The latest example from astrophysical observations is the supernova explosion that occurred early in 1987 [designated SN1987A (1)]. Electromagnetic radiation, from radio waves to gamma rays, as well as a neutrino burst have been detected. Astrophysicists are anxious to detect new signals, which are either directly or indirectly related to the particle acceleration processes, such as acceleration at the supernova shock wave, stochastic acceleration in the turbulence generated in the supernova ejecta, or acceleration by the strong pulsar electric field. Astrophysical observations, however, are remote-sensing observations. In the foreseeable future, we will not be

able to make in situ observations of shock waves from supernovae. Because physics is an experimental science, we need a laboratory in which we can test basic principles. In this respect, the heliosphere, within which the solar wind plasma has the greatest influence on the dynamics and the energetics of particles, can be considered as a laboratory for particle acceleration processes. Of course, the parameter regime that we can reach in heliospheric observations is rather limited. Nevertheless, in this way we can learn much about the elementary principles that govern particle acceleration processes.

Let us start with an elementary consideration of the motion of charged particles in cosmic plasmas permeated by magnetic fields. Charged particles are most efficiently accelerated by the electric field, and the effects of other forces, such as gravity, are negligible. However, the electric field does not always accelerate these particles freely if the background plasma is steady and homogeneous: $\mathbf{E}_\perp$, the electric field component perpendicular to the magnetic field, $\mathbf{B}$, can only produce $\mathbf{E}_\perp \times \mathbf{B}$ drift motion (that is, magnetized motion). Suppose that the magnetic field is directed toward the page and that the electric field is directed downward (Fig. 1). A particle (of mass m), which is initially at rest, makes a cycloid motion in configuration space (Fig. 1a). The average speed of this particle is

$$\mathbf{V}_E = c \frac{\mathbf{E}_\perp \times \mathbf{B}}{|\mathbf{B}|^2} \quad (1)$$

where c is the vacuum speed of light. In velocity space, the orbit of this particle is a circle (Fig. 1b). The maximum velocity a particle can obtain is $2|\mathbf{V}_E|$. The corresponding maximum energy, $2m|\mathbf{V}_E|^2$, is now known as the maximum "pickup" energy. (This name is derived from the study of cometary ions. See the next section.) To accelerate this particle to energies higher than this maximum pickup energy, it is necessary to break the magnetized motion so that the particle can move along the direction of $\mathbf{E}_\perp$. In the following sections, we shall discuss stochastic acceleration processes in unsteady plasmas, in which such a breakdown becomes possible.

Another way to accelerate particles efficiently is to have an electric field component parallel to the magnetic field, $E_\parallel$. Because the magnetic field does not prevent particle acceleration along it, $E_\parallel$ can accelerate particles freely. However, $E_\parallel$ is easily short-circuited

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