The Trial Process

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Mathematical Models of Juror and Jury Decision-Making

THE STATE OF THE ART

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INTRODUCTION

> The jury is a remarkable example of the use of groups to make decisions. A jury is composed of untrained citizens, drawn randomly from the eligible population, convened briefly for a particular trial, entrusted with great official powers, permitted to deliberate in secret, to render a verdict without explanation, and without any accountability then or ever, to return to private life. In that such a firm institution is composed of such fluid members, and that these ordinary citizens judge criminal responsibility in place of professional agents of the state, the jury is a unique political institution. More than representative legislatures and popularly elected executives, it is the jury that characterizes democratic political systems. (Saks, 1977, p. 6)

The twelve-member unanimous jury was introduced into the American colonies by Great Britain and became a fixture of American legal procedure which was copied by states which subsequently entered the union. For most Americans, the notion of "trial by jury" is synonymous with judgment by a group of twelve members which requires unanimity of its members to reach a verdict. Historically, however, even in the United States, juries have varied in size and decision requirements, with smaller juries and the absence of a unanimity requirement relatively

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common in civil cases (Bloomstein, 1968). Recently, reversing earlier precedents, the United States Supreme Court has upheld the constitutionality in state criminal cases of juries which do not require unanimous verdicts and of juries with less than twelve members.[1] What minimum size and what minimum decision rule the court will ultimately decide the Sixth Amendment does require is, as far as we can tell, impossible to determine from the Court's reasoning in these cases (Grofman, 1974). The rulings have generated impetus in state legislatures to move to smaller juries and/or to less than unanimous verdicts in both criminal and civil cases (Oelsner, 1975).

The Supreme Court's rulings have also triggered a great deal of interest in jury decision-making on the part of social scientists. There have been at least three times as many studies involving juries or mock juries done in the 1970s as in the previous two decades combined. Recent research has looked at a range of questions, but much of it has dealt with variations in the jury size and the decision rule; the nature of the jury selection process; and the personality and demographic characteristics of individual jurors in terms of consequences for the nature of jury verdicts, the process of group deliberation, the reliability of the jury as a fact finder, the representativeness of juries as a community cross section, and the vulnerability of jurors in the minority to conformity pressures by the majority. Most of this recent work stems from an experimental social psychological tradition (see Tapp, 1976). Because there are a number of extensive reviews of the empirical and experimental literature on jury decison-making (see, e.g., Bray, 1976; Davis, Bray, & Holt, 1977; Factor, Eisner, & Shaw, 1977; Gerbasi, Zuckerman, & Reis, 1977; Saks, 1977), we shall deal with this literature only as it relates to our primary focus on formal models of juror and jury decision-making.

We shall look first at the nature of juror choice in the general context of statistical decision theory and in terms of the expected predeliberation distribution of verdict preferences and judgments among a group of jurors of size N drawn from a larger jury pool of specified characteristics. We shall then examine, for different jury sizes, ways in which individual

[1]In *Williams* v. *Florida* 398 U.S. 78 (1970), the Court upheld the constitutionality of felony convictions by state juries of less than twelve. In reviewing *Johnson* v. *Louisiana* 406 U.S. 356 (1972) and *Apodaca* v. *Oregon* 406 U.S. 404 (1972), the Court held that 10 to 2 and 11 to 1 decisions (in Oregon) and a 9 to 3 decision in Louisiana did not violate the 6th Amendment right to a jury trial. In *Colgrove* v. *Battin* 413 U.S. 149 (1973), the Court upheld six-member civil juries in Federal Courts.

We might also note that in United States military court-martials, except for those carrying a mandatory death penalty, unanimous agreement is not required. General court-martial "juries" may be composed of as few as five members, although panels of seven, nine, or eleven are more common (Larkin, 1971, p. 238).

predeliberation juror verdict preferences and judgments might come to be aggregated into a final group verdict under various assumptions as to the nature of the process of majority persuasion–minority conformity in the group and the specific quorum rules required for decision-making. Finally, we shall examine closely the impact of variation in the jury size and the decision rule on verdict outcomes, and on the probabilities of Type I and Type II errors.[2] In our discussion we shall confine ourselves to criminal trials and, unless otherwise indicated, to cases where the juror choice is dichotomous—acquittal or conviction.

SIGNAL DETECTION MODELS OF JUROR DECISION-MAKING

Guilt Beyond a Reasonable Doubt

The task set for jurors is to evaluate the evidence and to determine on the basis of it the defendant's guilt or innocence of the crime of which he is accused. We can conceptualize this task in terms of some well known results in the theory of signal detectability (see, e.g., Coombs, Dawes, & Tversky, 1970, Chap. 6; Restle & Greeno, 1970, Chap. 5).

Signal detection models contain two distinct components. One component is a model of the observer as a sensor, that is, of his ability to discriminate stimuli. The second component is a model of the observer as a decision-maker, that is, of the effects of his values and expectations on his responses.

> These two aspects are confounded in performance. One doctor may more often prescribe treatment for an allergy than another doctor—he may more often be right but also more often be wrong. Is he a more sensitive detector or is he more willing to say yes? The theory of signal detectability makes it possible to distinguish these two aspects precisely. (Coombs *et al.*, 1970, p. 166)

Consider an individual observing some given stimulus. In the usual detection experiment the subject's task is to decide "yes" or "no" as to whether the stimulus was generated by a "signal" or whether it was merely the product of "noise." The language and concepts of signal detection theory may, however, be applied by analogy to any context in which the sensory input is ambiguous. In the juror case, we may imagine that jurors seek to monitor "evidence (appearance) of guilt," which

[2]For a discussion of various other aspects of juries and jury decision-making, for example, group memory, jury variability in assessing damage awards, representation of minority viewpoints, participation hierarchies in group discussion, jury factionalization, the voir dire process, and so forth, see Grofman (1976a, 1977a) and Grofman and Feld (1976).

is analogous to amplitude of the signal. On the basis of his or her assessment of the extent to which the defendant appears guilty, a juror must decide whether or not to convict. This assessment, however, is uncertain. The observed level of apparent guilt has some probability of having arisen (as "signal") from the behavior of a guilty defendant, but also some probability of having arisen (as "noise") by chance from a defendant who is really innocent. We can view the juror's task in terms of discriminating between the probability distributions shown in Figure 1. For any given point on the x-axis, say $x_{c'}$, labeling all defendants whose trials rise to an appearance of guilt at least as great as x_c would lead to a "hit" probability. $p_{C|G}$ (the conditional probability of convicting a guilty defendant) and a "false alarm" rate, $p_{C|I}$ (the conditional probability of convicting an innocent defendant), as shown in Figure 1. Since in the Unites States we consider innocence to be the null hypothesis, it is easy to see that for any given criterion value, x_c, we are imposing a tradeoff between Type I error (i.e., rejecting the null hypothesis when it is, in fact, true; convicting the innocent) and Type II error (i.e., accepting the null hypothesis when it is, in fact, false; freeing the guilty). The further to the right we move x_c, the lower the probability of Type I error, but also the higher the probability of Type II error.

So far the discussion has been couched in familiar hypothesis test-

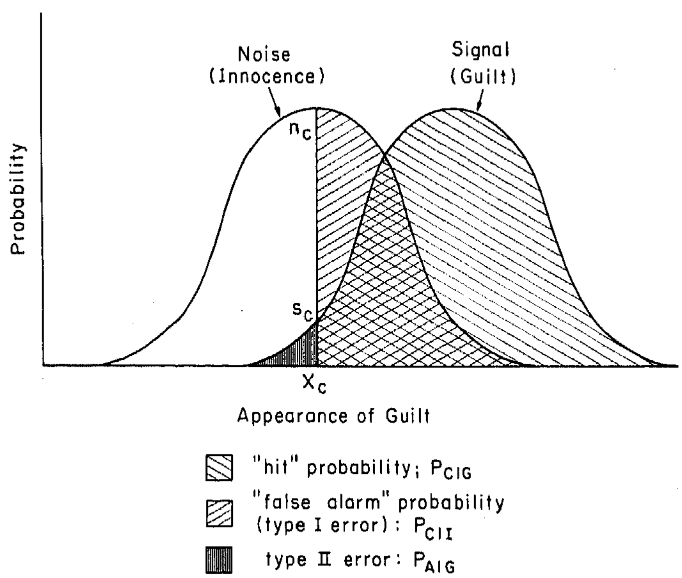

Fig. 1. Determination of guilt by discrimination between probability distributions of "signal" and "noise."

ing terms (see, e.g., Feinberg, 1971). Signal detection theory, however, is Bayesian in orientation and is couched in terms of likelihood ratios, rather than significance regions. Let us look again at the criterion level x_c. For each level we have a likelihood ratio

$$\ell(X) = \frac{p(x|G)}{p(x|I)} = \frac{\overline{sx}}{\overline{nx}} \quad (1)$$

The probability of observing a value of x if the defendant were guilty is symbolized by $p(x|G)$. Similarly, $p(x|I)$ represents the probability of obtaining an appearance of guilt of level x if the defendant were indeed innocent. These conditional probabilities are given by the line lengths $\overline{sx}$ and $\overline{nx}$, respectively. It can readily be shown that, for "reasonable" assumptions about the probability distributions shown in Figure 1, the farther x_c is to the right, the greater is the value of the likelihood ratio. Thus, we may use the likelihood ratio to establish a criterion for declaring guilt, since if we convict all defendants for whom

$$\ell(x_c) \leq \frac{\overline{nx}_c}{\overline{sx}_c} \quad (2)$$

we will convict all defendants whose appearance of guilt falls to the right of x_c.

We shall now look at how a criterion value for $l(x)$ might be chosen in terms of convicting only those defendants whom a juror believes to be guilty "beyond a reasonable doubt" and then in terms of specifying explicit values (weights) to "freeing the innocent" and "convicting the guilty," respectively.[3]

[3]We have chosen to conceptualize the standard of "beyond a reasonable doubt" as a standard for juror choice. As Kerr, Atkin, Stasser, Meek, Holt, and Davis (1976, p. 282) note, "[V]erdicts are group decisions. Reasonable doubt may be interpreted as both an individual and a group decision criterion. As an individual choice criterion it relates to the degree of certainty about the defendant's guilt which a juror must feel before assenting to a guilty verdict. As a group criterion, it may be related to the degree of group consensus required for a guilty verdict." We believe it important to distinguish carefully between these two usages, and we shall reserve the term "reasonable doubt" for the individual juror. When discussing group decisions later in the paper we shall talk about jury verdicts in terms of their "reliability" and/or "accuracy." Thus, we reject the view of some legal scholars that "the unanimity of verdict in a criminal case is inextricably interwoven with the required measure of proof... for there cannot be a verdict supported by proof beyond a reasonable doubt if one or more jurors remain reasonably in doubt as to guilt. It would be a contradiction in terms" (Judge Simons, cited in Larkin, 1971, p. 243). For more on this point see Kerr *et al.* (1976), Saks (1977, pp. 24–27), and discussion below. For evidence dealing with jurors' perceptions (or lack thereof) as to the meaning of "beyond a reasonable doubt," see Simon and Mahan (1971) and Strawn and Buchanan (1976).

Consider $(p(G|x)$. This is the conditional probability that a defendant is guilty given some observed appearance of guilt x. A juror might wish to choose x_c such that only if

$$p(G|x) \geqslant p(G|x_c) \tag{3}$$

would he be willing to convict, where $p(G|x_c)$ reflects the probability which defines for that juror a standard of guilt "beyond a reasonable doubt." Since $p(G|x_c)$ increases as x_c moves to the right, choosing a value for $p(G|x_c)$ is equivalent to choosing a criterion value for x. Let us label as p the probability, $p(G|x_c)$, which the juror minimally requires to satisfy his standard of "beyond a reasonable doubt." From Bayes theorem we have

$$p(G|x) = \frac{p(x|G)p(G)}{p(x)} \tag{4}$$

where $P(G)$ is the *a priori* expected proportion of defendants who are guilty, and similarly

$$p(I|x) = \frac{p(x|I)p(I)}{p(x)} \tag{5}$$

Hence,

$$\frac{p(G|x)}{p(I|x)} = \frac{p(x|G)p(G)}{p(x|I)p(I)} \tag{6}$$

$$= \ell(x)\frac{p(G)}{p(I)}$$

The ratio on the right-hand side

$$\frac{p(G)}{p(I)}$$

is often referred to as the "prior odds"; the ratio on the left-hand side gives the "posterior odds." Let us define

$$\frac{p(I)}{p(G)} = \Omega \tag{7}$$

We know that

$$p(G|x) + p(I|x) = 1 \tag{8}$$

Hence, if $p(G|x) = p$, then $p(I|x) = 1 - p$. Similarly, if we require $p(G|x) \geqslant p$, then $p(I|x) \leqslant 1 - p$. Thus, to require guilt beyond a reasonable doubt is to require

$$\frac{p(G|x)}{p(I|x)} \geqslant \frac{p}{1-p} \tag{9}$$

Making use of the identity in Equation (6) we may express our requirement of guilt "beyond a reasonable doubt" in terms of (x) as follows:

$$\ell(x) \geqslant \Omega \frac{p}{1-p} \tag{10}$$

This is an important expression because it shows us how the standard of discrimination depends both on the juror's criterion for guilt beyond a reasonable doubt and on his estimate of the *a priori* odds. The higher his *a priori* estimate of the proportion of innocent defendants being brought to trial (as evidenced in Ω) and the higher his standard of guilt beyond a reasonable doubt (as evidenced in p), the higher the value of $l(x)$ the juror requires in order to convict, and thus the further to the right will he set his criterion value of x_c.[4]

The reader should satisfy himself as to why Ω enters into Equation (10). To see why, let us compare the case where most (say, 9 of 10) defendants brought to trial are expected to be guilty (Distributions II and III in Figure 2) to that where $p(G) = p(I) = 1/2$ (Distributions I and III in Figure 2). For simplicity, let our standard of reasonable doubt be $p \geqslant .5$.

[4]We might weigh the disutility of convicting an innocent man differently in different cases. "The better the reputation of a defendant, the greater the tragedy of his fall from grace, and hence, perhaps the greater disutility of convicting him should he be innocent. If so, we perhaps have an explanation of the relatively powerful effect of character testimony on behalf of a criminal defendant. In addition to the usual justification—that the evidence of the good character of the defendant makes it less likely that he in fact committed the crime—we have a second reason: that by raising the disutility of convicting the defendant should he be innocent, we raise the quantum of proof or probability of guilt necessary to convict. Converse reasoning makes clear a very important reason for excluding evidence of previous convictions from the prosecution's case. Not only may such evidence lead the jurors to the wholly rational conclusion that if the defendant has committed previous crimes he is more likely to be guilty of this one; it may also lead them to the perhaps rational but *clearly undesirable conclusion* that because of his earlier convictions, the disutility of convicting the defendant should he be innocent, is minimal" (Kaplan, 1968, p. 1074, emphasis ours). According to Kaplan (1968, p. 1074), "[T]he observed high rate of conviction in the south of Negroes for crimes against white persons may be explained not only by the typical white southern juror's view that the white complainant is always telling the truth, but also by his low estimate of the disutility of convicting an innocent Negro and his high estimate of the disutility of letting a guilty Negro get 'away' with something." In other words, according to Kaplan, for many southern white persons, R may be less than one for black defendants and thus even a small probability of guilt may be seen as sufficient to convict.

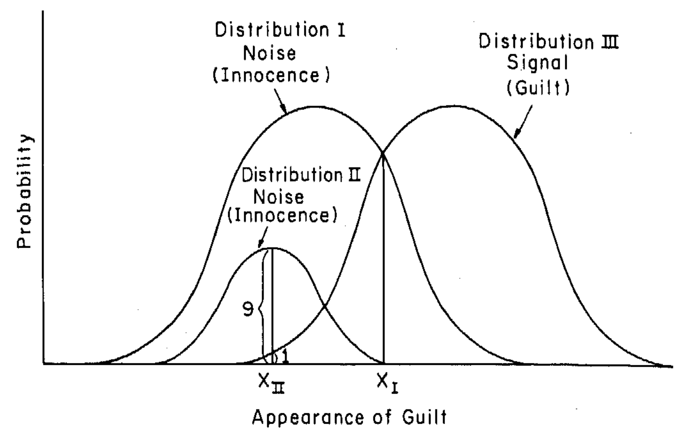

Fig. 2. Hypothetical distribution of Type I and Type II errors in a signal detection model.

In Figure 2, the point x_I indicates that cutoff we would use to guarantee that the probability was at least .5 that any defendant we convicted was indeed guilty (i.e., that at least half the defendants we convicted were guilty) when Distributions I and III represent the conditional probability distributions of guilt and innocence, respectively. In Figure 2, the point X_{II} indicates the threshold we would use for the same purpose when Distribution II rather than I represents the conditional probability distribution of innocence. As we see, for a fixed minimum probability defining "beyond a reasonable doubt," the $l(x)$ threshold value (and thus the x_c threshold value), is lowered when the a priori probability of guilt is lowered. Roughly speaking, the fewer the innocents there are to be convicted, the easier it is for us to convict more readily without raising the ratio of innocents to guilty among those convicted beyond our threshold value of p. Analogously, of course, for Ω fixed, the $l(x)$ threshold value (and thus the x_c threshold value) is lowered when p (the defining standard for "beyond a reasonable doubt") is lowered.

The Juror Payoff Matrix

Let us now turn to an explicit representation of $l(x)$ in terms of values (weights) to be attached to the four possible outcomes: $C \wedge G$, $C \wedge I$, A, $\wedge G$, and $A \wedge I$, where $C \wedge G$ refers to the outcome where a guilty defendant is convicted, $A \wedge I$ refers to the outcome where an innocent defendant is acquitted, and so on. Consider the matrix shown in Figure 3. Let C be a verdict of conviction and A a verdict of acquittal.

	C	A
G	$V_{C \wedge G}$	$-V_{A \wedge G}$
I	$-V_{C \wedge I}$	$V_{A \wedge I}$

Fig. 3. General payoff matrix for juror choice.

Let G represent the state of nature in which the defendant is guilty and I the state of nature in which the defendant is innocent. We use $V_{C \wedge G}$ to indicate the value to the juror of convicting a guilty defendant and $V_{A \wedge I}$ the value to the juror of acquitting an innocent defendant. Since, presumably, jurors would prefer to avoid Type I and Type II error, that is, would prefer to avoid convicting the innocent and/or freeing the guilty, we show the values for those outcomes in the matrix of Figure 3 as being negative. Suppose the juror wishes to maximize his expected value. This means that, given an observation of appearance of guilt x, the juror votes for conviction if the expected value of a C choice is greater than the expected value of an A choice. The expression for the expected value of C given the observation x is the value $V_{C \wedge G}$ times the conditional probability that the defendant was guilty minus $V_{C \wedge I}$ times the conditional probability that the defendant was innocent, that is,

$$E(C|x) = V_{C \wedge G}\, p(G|x) - V_{C \wedge I}\, p(I|x) \tag{11}$$

Similarly, the expression for the expected value of choice A given x is

$$E(A|x) = V_{A \wedge I}\, p(I|x) - V_{A \wedge G}\, p(G|x) \tag{12}$$

Maximizing expected value requires that the juror vote for conviction if and only if

$$E(C|x) > E(A|x) \tag{13}$$

Substituting and rearranging we obtain as the condition for choice of C:

$$\frac{p(G|x)}{p(I|x)} > \frac{V_{A \wedge I} + V_{C \wedge I}}{V_{C \wedge G} + V_{A \wedge G}} \tag{14}$$

If we substitute the identity of Equation (6) we may restate this condition in terms of $\ell(x)$ and Ω as follows: choose C if and only if

$$\ell(x) > \Omega \left(\frac{V_{A \wedge I} + V_{C \wedge I}}{V_{C \wedge G} + V_{A \wedge G}} \right) \tag{15}$$

If, as before, we denote the criterion value for $p(G|x)$ as p, we can express the results given in Equation (14) in terms of the values shown in the matrix of Figure 3 and our standard of reasonable doubt. However, we shall not bother to do so. Rather, we shall first propose a simplified form of the matrix given in Figure 3.

Without great loss of generality, let us assume that the utility of acquitting the innocent is R times as great as that of convicting the guilty. Similarly, let the disutility of convicting the innocent be R times as great as the disutility of acquitting the quilty. This leads us to the payoff matrix shown in Figure 4. Substituting the values given in Figure 4 in Equation (14), we obtain

$$\frac{p(G|x)}{p(I|x)} > R \tag{15}$$

If we let our threshold probability for $p(G|x)$ be p, as before, we obtain as our condition for choice of C:

$$\frac{p}{1-p} > R \tag{16}$$

or equivalently,

$$p > \frac{R}{R+1} \tag{17}$$

This last expression has a very nice interpretation. Let the tradeoff ratio R equal the number of guilty defendants a juror is willing to set free to prevent one innocent person from being convicted. Under the payoff assumptions shown in the matrix of Figure 4, Equation (17) shows that a juror, by setting R, is implicitly choosing a threshold value p. Analogously, by setting a threshold probability p, a juror is implicitly assigning a value to R. For the payoff matrix of Figure 4 we may also express the expected utility maximizing rule in terms of (x), R, and Ω: choose C if and only if $l(x) > \Omega R$.

In criminal cases, it may be argued that R should be greater than one, that is, we should be more concerned about protecting the innocent

	C	A
G	1	-1
I	-R	R

Fig. 4. Simplified payoff matrix for juror choice.

from unjust conviction than about ensuring that the guilty are convicted of their crimes. Such a belief would explain the criminal law's insistence that in order to convict, the jury must be convinced "beyond a reasonable doubt" (see Kaplan, 1968, pp. 1065–1092). Nineteenth-century legal scholars (e.g., Blackstone) argued for various R values ranging from five to as high as 20 in capital cases (see Kaplan, 1968, p. 1077).

In civil cases, the implicit standard is $R = 1$, "the preponderance of the evidence test" where "the jury must merely be satisfied that the probability is greater than 50% or—in other words that it is more likely than not that the plaintiff has a right to recover" (Kaplan, 1968, p. 1072).

> The assumption of equal disutilities that the preponderance-of-the-evidence test reflects does not completely pervade our noncriminal law, however. In certain cases we typically require that a party demonstrate certain facts to a higher degree of probability. Thus, where the defendant is accused of fraud, a finding against him may do more than merely cost him money. Since he loses reputation as well, the disutility of an erroneous judgement against him may be greater than that of an erroneous judgement against the plaintiff; as a result we demand that the plaintiff prove his case to a higher probability—clear and convincing evidence. The clear-and-convincing-evidence requirement is applied in two other situations—one of which is a denaturalization hearing. (Kaplan, 1968, p. 1072)

The ROC Curve

The performance of a juror who decides whether or not to vote a defendant guilty on the basis of a threshold value for $l(x)$ can be completely described by what is called the *receiver operating characteristic curve* or ROC curve. We have posited that the observer (juror) says yes (convicts) wherever the observation x exceeds the critical value x_c. As may be seen in Figure 1, the area under the signal distribution above the point x_c is the proportion of times the juror convicts the guilty, that is, the probability of a hit, and the area under the noise (innocence) distribution above the same point is the proportion of times the juror convicts the innocent.

The ROC curve is based on the hit rate and the false alarm rate. For any given x_c "all the information about the receiver's performance is contained in the hit and false alarm rates" (Coombs *et al.*, 1970, p. 175). For a given hypothetical juror, we plot against each other his hit and false alarm rates for each possible value of x_c. These values fall along a curve in the unit square, shown in Figure 5, which is known as the ROC curve. The performance of an observer, under a fixed set of conditions, corresponds to a point on an ROC curve. The diagonal line is the expected ROC curve if the receiver does not discriminate between signal

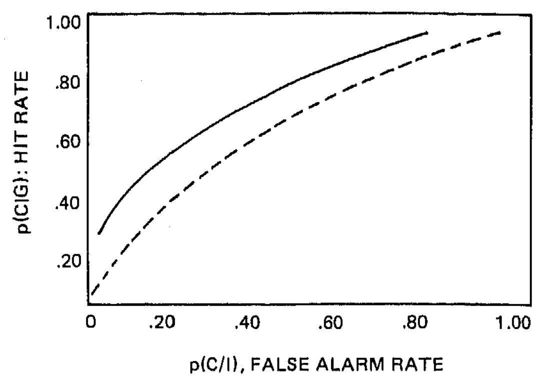

Fig. 5. Hypothetical ROC curves for two cases: solid line "easy"; dashed line "hard"; or alternatively, for two jurors: Solid line "discriminating" juror, dashed line "undiscriminating" juror.

and noise, that is, does not discriminate between the innocent and the guilty. The further to the right on this diagonal, the greater the bias for conviction. "As the cutoff x_c moves from left to right . . . the corresponding point on the ROC curves moves from right to left" (Coombs *et al.*, 1970, p. 176).

Intuitively it is clear that the ROC curve can, for any given trial, be expected to differ across jurors, and for any given juror, be expected to differ across trials. Some jurors will be more discriminating than others, that is, better capable of distinguishing, for any level of apparent guilt, between the innocent and the guilty. Similarly, some trials will be "easier" than others:

> In [the figure] imagine the signal distribution shifted to the right some fixed amount. If the false alarm rate is kept the same as before by leaving x_c where it is in [the figure] clearly the hit rate will increase as there is more area under the signal distribution to the right of x_c than before. As the hit and false alarm rates are the coordinates of a point on an ROC curve, this point would lie directly above the point before the signal distribution was shifted. This relation would hold for any value of x_c, so there is a new ROC curve generated lying above the previous one. (Coombs *et al.*, 1970, p. 177, with some change in notation)

Shifting the signal distribution to the right makes any juror's task easier. Signal detection theory permits us to precisely conceptualize the difference between "easy" cases and "hard" cases in terms of the overlap between signal distribution and noise distribution and the ROC curve.[5] For a given hypothetical juror, we show in Figure 5 two

[5]It is possible to make this notion of overlap more precise, but we shall not pursue the issue further here. See Coombs *et al.* (1970, pp. 177–180).

hypothetical ROC curves, one for an "easy" case and one for a "hard" case. Alternatively, we could conceptualize these curves as being generated by only one case, but coming from two different jurors, one more discriminating than the other. We shall make use of the idea of the basic ideas of the ROC curve when we consider one- and two-parameter models of juror choice below (pp. 324–330).[6]

MULTIPLE VERDICT OPTIONS

Juror Choice as a Function of Verdict Severity

Decision-making, whether by individuals or by groups, frequently involves choosing from among a set of more than two alternatives. In criminal trials, jurors may be confronted with multiple verdict options when they are given the option of convicting the defendant of a "lesser included offense."[7] What options jurors have open to them may have important verdict consequence. For example, Vidmar (1972) argues that in the Algiers Motel case, the restriction of jurors' verdict options to not guilty or guilty of first degree murder may have led to an unnecessarily harsh jury verdict, because jurors unwilling to acquit but unable to opt for convicting of a lesser offense were forced into a first degree murder conviction by the limited options available. Recently, Vidmar (1972), Larntz (1975), and Grofman (1975a) have each proposed models of the impact of constrained choices on the verdicts of mock jurors. We shall review the models used by those authors, and present relevant data from a jury simulation conducted by Hamilton (1976) in which mock jurors were given either two verdict options (not guilty and guilty of

[6]General questions dealing with the nature of juror judgmental processes and evidence integration are dealt with in Finkelstein and Fairley (1970). For an insightful and carefully reasoned article on the use of probabilistic reasoning and cost-benefit calculations in the legal process, see Tribe (1971). This is an article which we recommend highly, although we do not share Tribe's quite skeptical views on the limitations of mathematical tools for the law.

[7]However, Kaplan (1968, p. 1081) points out that this case is not as important in criminal law as one might first think:

> In the lesser included offense situation there usually will be only one intermediate offense (in the case of first-degree murder, two) so that a conviction of a lesser offense is much less likely to minimize the expected regret. Furthermore, the probability that the defendant is in fact guilty of the lesser offense may be so low that although there are high disutilities involved in each of the extreme choices, one of them will nonetheless be preferable to the lesser included offense. Thus, the jury, in choosing between grand larceny and acquittal, may be unable to embrace a petty larceny verdict if the amount stolen is clearly above the dividing line. Similarly, in a homicide case in which the defendant disputes identity and enters an alibi defense, it is rare for the jury to convict of manslaughter.

premeditated murder) or three (not guilty, guilty of unpremeditated murder, and guilty of premeditated murder).

Vidmar (1972) argued that chances of obtaining acquittal increase with the severity of the least severe nonacquittal verdict option available. He stressed the roles of jurors' perceptions of the fairness of conviction in producing this result. He experimentally tested his hypothesis using a summary of an actual second-degree murder case. His subjects were students who simulated jurors, who did not deliberate but simply came to individual decisions on the case. With a variety of two-, three-, and four-verdict option conditions, his data (aggregated individual verdict choices) produced strong support for the hypothesis. For example, in the choice between first-degree and acquittal, 54% of the jurors voted for acquittal; in the choice among all four verdict options, only 8% voted for acquittal.

Larntz (1975) took issue with Vidmar's interpretation of his data, and proposed a simple probabilistic model. He argued that verdicts x, y, z, and so on, are chosen in restricted option conditions, in proportion to the frequency of their choice in the unrestricted choice condition, that is,

$$\frac{p(x|S)}{p(y|S)} = \frac{p(x|R)}{p(y|R)} \tag{19}$$

Larntz's model can't be rejected for the Vidmar data ($\chi^2 = 16.5$, $df = 9$, $p > .05$). Larntz's model offers an aggregate level analogue to Luce's (1959) choice axiom.

Grofman (1975a) has presented a third approach to the restriction of decision alternatives (and to the Vidmar, 1972, data). He generalized Vidmar's (1972) hypothesis, showing it to be subsumed as a special case of a general scaling model; this model postulated that each juror effectively orders whatever options are available to him according to severity of consequences to the defendant, and that he chooses that available option which is closest to the point on the continuum that represents what Coombs (1964) refers to as his "ideal" point. The Grofman (1975a) model accounts for the Vidmar (1972) data better than Larntz's (1975) alternative hypotheses and more fully than does Vidmar's own hypothesis (see Grofman, 1975a, for details).

Grofman's (1975a) approach can be briefly illustrated using Hamilton's (1976) three decision alternatives: not guilty (N), guilty of unpremeditated murder (U), and guilty of premeditated murder (P). Consider the verdict alternatives as on a continuum NUP with respect to verdict severity, and consider an individual whose most preferred verdict outcome is at some point on this continuum. In general, a curve is said to be single-peaked if it changes its slope at most once from up to down

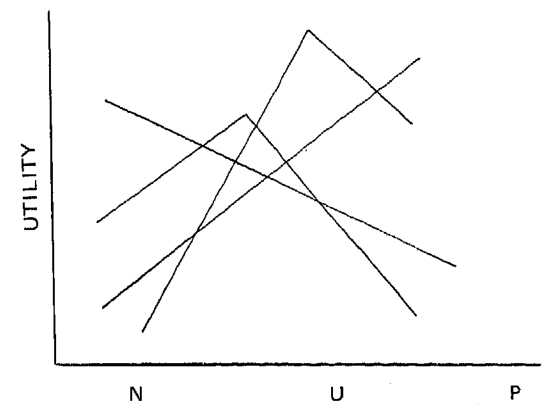

Fig. 6. Single-peaked curves along a severity dimension.

(Black, 1958; Grofman, 1969); Grofman (1975a) postulates that all juror preference orderings of verdict options are single-peaked on a severity-based continuum. This means that if the individual juror's verdict preference function is indeed single-peaked with respect to the *NUP* continuum, then it can be represented as one of the four patterns in Figure 6. Of the six possible ways of ordering three items, the assumption of single-peakedness permits four possible preference orderings: *NUP*, *UNP*, *UPN*, and *PUN*. It precludes the other two: *NPU* and *PNU*. In any choice among these alternatives (pairwise or not), that alternative is preferred which is closest in utility to the individual's most preferred outcome. Actual utility assignments—that is, the desirabilities to the juror of each of the three verdicts—are irrelevant for purposes of this model. All that matters is the ordinality of the preference orderings.

Subjects in Hamilton's (1976) mock jury experiment were administered a questionnaire which included questions about verdict and verdict certainty; half of the subjects were allowed to choose only between not guilty and guilty of premeditated murder, while half had the additional option of guilty of unpremeditated murder. Fifty-eight subjects completed this portion of the experiment. Subjects were also asked to rate the fairness, on a scale from 0 (not at all fair) to 100 (completely fair), of each of four verdicts: *N*, *U*, *P*, and manslaughter, *M*.[8] Fairness judgment data is available for 56 of the 58 subjects.

Table I presents the verdict distributions by experimental conditions. Hamilton's (1976) data bear out Vidmar's (1972) hypothesis: ac-

[8]We shall omit the data dealing with fairness judgments of manslaughter in the discussion that follows.

TABLE I. VERDICT PREFERENCES BY VERDICT-OPTION CONDITIONS IN HAMILTON (1976) DATA

	N	*U*	*P*
Two-option condition	.70 (20)		.31 (9)
Three-option condition	.38 (11)	.52 (15)	.10 (3)

Note. 58 subjects.

quittals decreased from 70% to 38% when the unpremeditated murder verdict was permitted as an option. On the other hand, the Larntz (1975) model applied to Hamilton's (1976) data does not yield a good fit. The ration of P to N verdicts in the three option condition is 3/12 (.25) while the analogous ratio in the two option condition is 9/20 (.45). The Larntz (1975) model predicts these two ratios to be identical.

We may also check to see whether verdicts were chosen consistently with a single-peaked preference ordering. Let x_1 = the fraction of jurors with preference ordering *NUP*, x_2 = the fraction of jurors with preference ordering *UNP*, x_3 = the fraction of jurors with preference ordering *UPN*, and x_4 = the fraction of jurors with preference ordering *PUN*. Under our single-peakedness assumption, if we assume that the underlying preferences of jurors are unaffected by whether they have been put in a 2-verdict or a 3-verdict condition, then we may reconstruct the underlying preferences of our jurors by attempting to solve the following set of independent equations (see Grofman (1975a) for mathematical details):

$$x_1 + x_2 = \frac{20}{29} \qquad (20)$$

$$x_3 + x_4 = \frac{9}{29}$$

$$x_1 = \frac{11}{29}$$

$$x_2 + x_3 = \frac{15}{29}$$

Since this equation set has a consistent solution, namely $x_1 = 11/29 = (.38)$, $x_2 = 9/29 = (.31)$, $x_3 = 6/29 = (.20)$, and $x_4 = 3/29 = (.10)$, we do not reject the assumption of single-peakedness.

We are, however, in a position to test the single-peaked assumption more directly than was possible with the Vidmar (1972) data, if we assume that verdicts are preferred in order of fairness. Then, by looking at the individual juror's fairness rankings of the *P*, *U*, and *N* verdicts, we may establish each juror's preference ordering over these verdict options. Under this assumption as to the relationship between verdict fairness and verdict choice, the hypothesis that verdict preferences are single-peaked is strongly supported in Hamilton's (1976) data: 55 of the 56 mock jurors for whom we have fairness data exhibit single-peaked preference.

However, the link between perceived verdict fairness and verdict choice is in actuality not perfect. Four of the 56 jurors violated this decision rule. In the two-verdict option case, a juror with (nonsingle-peaked) preference *PNU* voted for acquittal. In the three-verdict option case, three of the 14 jurors with preferences *NUP* voted for unpremeditated murder rather than acquittal. There are, also, certain other features of Hamilton's (1976) data that suggest the need for caution in interpreting her findings as support for a single-peaked model of juror choice. Even though we cannot reject the null hypothesis that the juror preference orderings in the two-option and three-option conditions are derived from the same population; in Hamilton's (1976) data the proportion of *PUN* orderings is higher in the two-option condition than in the three-option condition, while the proportion of *UPN* orderings is higher in the three-option than in the two-option condition. Such a finding suggests the possibility of an anchoring effect (Parducci, 1963; Sherif & Sherif, 1967) in which the introduction of the unpremeditated murder verdict option in the three-option condition reduces jurors' perceived fairness of premeditated murder and/or increases their perceived fairness of unpremeditated murder in such a way as to shift some jurors from a *PUN* to a *UPN* ordering. We shall not, however, attempt to pursue this issue further here.

As one final point, in the case of multiple verdict options, the existence of a single-peaked ordering underlying juror preferences eliminates the probability of a "paradox of cyclical majorities." Consider three individuals A, B, C and three alternatives x, y, and z. Assume the individuals have transitive preference orderings:[9] xyz, yzx, and zxy, respectively. If they must choose an alternative by majority voting, the group's preferences are not transitive since x receives a majority over y and y receives a majority over z, but z receives a majority over x. This cycle among alternatives is known as the paradox of cyclical majorities.

[9]An ordering is said to be transitive if x preferred to y and y preferred to z guarantees that x is preferred to z.

In the case where there is a paradox of cyclical majorities the order in which alternatives are voted on is often crucial in determining the group choice (see Grofman, 1969). Analogous cycles can obtain for any quorum rule other than unanimity. Even in the case of unanimous verdicts, "unless all the jurors prefer the same action some will have to retreat on their preferences in order to secure a unanimous verdict" (Kaplan, 1968, p. 1081). Thus, multiple verdict options could be expected to (a) result in deadlock, or (b) result in a paradox of cyclical majorities where no one verdict alternative is the "clear" group choice, or in manipulation of verdict choice based on the order in which alternatives are voted. However, Black (1958) has shown that when preferences are single-peaked, the paradox of cyclical majorities cannot occur.[10] Thus, we would anticipate that, when juror preferences are single-peaked, that verdict alternative which can receive a majority in paired contest versus each and every other verdict alternative would be the one chosen, and Black's (1958) theorem guarantees that for single-peaked preferences such an alternative will always exist.

Expected Regret

Kaplan (1968) has proposed a model of juror choice, minimizing expected regret, which can be extended to the multiple verdict options case, and which can be related to our discussion of single-peakedness. Consider the payoff matrix shown in Figure 3. Denote the ij entry of this matrix as V_{ij}. We may define a new "regret" matrix with entries

$$\left(\frac{\max V_{ij}}{i}\right) - V_{ij} \tag{21}$$

Such a matrix is shown in Figure 7.

Kaplan (1968) has proposed that jurors should prefer C to A if and only if their expected regret is less in the former than in the latter case, that is, if and only if

$$V_{C\wedge G}\, p(G|x) + V_{A\wedge G}\, p(G|x) < V_{A\wedge I}\, p(I|x) + V_{C\wedge I}\, p(I|x)$$

It is easy to see that this condition is identical to the expected utility maximizing condition previously expressed in Equation (13). More generally, we may readily show (Grofman, 1976b) that the rule "minimize expected regret" and the rule "maximize expected utility" are identical, even for cases where there are more than two alternatives.

[10]Strictly speaking, this result holds only for N odd. However, we may posit a tie-breaking mechanism for N even.

	C	A
G	0	$V_{C \wedge G} + V_{A \wedge G}$
I	$V_{A \wedge I} + V_{C \wedge I}$	0

Fig. 7. Regret matrix analogue to matrix shown in Figure 3.

Kaplan extends his analysis of the minimize-expected-regret rule to cases where jurors are confronted with multiple decision alternatives and presents a regret matrix for a four option case (M_1, 1st-degree murder; M_2, 2nd-degree murder; M_S, manslaughter; and I, acquittal) which we have reproduced as Figure 8. This matrix expresses values on a scale from 0 to 100 as assigned by a nonlawyer decision-theorist colleague of Kaplan (Kaplan, 1968, p. 1079).

In Kaplan's (1968, p. 1079) view, this matrix, while

> it probably corresponds to what most lawyers would write down as their regret matrix, . . . appears to show much too little regret over the conviction of the innocent or the conviction of the guilty of an unjustifiably severe offense. Thus, according to the matrix, the conviction of the defendant for manslaughter when in fact he was guilty of first-degree murder is just as regrettable as the conviction of first-degree murder of a defendant who is in fact guilty only of second degree murder.

While there are an infinite number of utility matrices compatible with the regret matrix shown in Figure 8, if, for simplicity, we let $V_{ii} = 100$, we obtain the utility matrix shown in Figure 9. Note that the payoffs shown in each column of this matrix are, in fact, single-peaked. Hence the verdict judgments of Kaplan's colleague also appear to reflect a unidimensional severity continuum.

Kaplan's (1968) model permits an important extension on the analysis offered by Grofman (1975a) in that it makes explicit the proba-

	V_{M_1}	V_{M_2}	V_{M_S}	V_I
M_1	0	5	10	20
M_2	10	0	5	15
M_5	40	15	0	10
I	100	70	40	0

Fig. 8. Kaplan's (1968) regret matrix for four-option case.

	v_{M_1}	v_{M_2}	v_{M_S}	v_I
M_1	100	95	90	80
M_2	90	100	95	85
M_5	60	85	100	90
I	0	30	60	100

Fig. 9. Utility matrix constructed from matrix of Figure 8 assuming $v_H = 100$.

bility component of juror choice in which jurors estimate the likelihood that a defendant is guilty of the various possible offenses and then pick that verdict alternative which maximizes their *expected* value (minimizes their *expected* regret).

NONDELIBERATIVE MODELS FOR AGGREGATING JUROR CHOICES AS A FUNCTION OF JURY SIZE AND JURY QUORUM RULE

THE ONE-PARAMETER MODEL

So far, we have looked only at the individual aspects of juror choice, using signal detection theory to characterize jurors in terms of an ROC curve and looking at juror utility and regret matrices. Clearly we need to know how juror choices come to be aggregated into a jury verdict. This aggregation can be expected to vary as a function of the predeliberation distribution of juror choices, and as a function of the persuasion–conformity process by which the jury comes to a consensus. Each of these factors might, in turn, be expected to vary as a function of jury size and jury quorum, that is, majority requirements. In this section, we will confine ourselves to models for predicting the predeliberation distribution of jury opinion. On p. 330 we will deal with modeling the impact of the group deliberation on jury verdict.

A simple model to predict the impact of jury size on the predeliberation distribution of verdict choices is one which postulates that jurors have some identical probability, p_C, of voting for conviction. Presumably p_C is a function of juror discrimination capacities and the "difficulty" of the case. (See our discussion of the ROC curve above. Note that p_C here has a different meaning than the p previously used.) This simple binomial model can be used for juries of sizes six and twelve, to predict the probability of a predeliberation majority of at least any given number or proportion. Results for 4/6 (8/12), 5/6 (10/12), or 6/6 (12/12) are shown in Table II.

This one-parameter binomial model (or a variant thereof) has been investigated by a number of authors (see, e.g., Auchmuty & Grofman, 1972; Davis, 1973; Davis *et al.*, 1977; Feinberg, 1971; Friedman, 1972; Gelfand & Solomon, 1973; Grofman, 1974, 1976b; Lempert, 1975a; Nagel & Neef, 1975, 1976; Saks & Ostrom, 1975; Walbert, 1971).

As we see from Table II, expected differences in predeliberation verdict distributions between juries of six and twelve depend heavily on the size of the special majority the probability of whose occurrence we are estimating, and on p_C. When p_C is high, expected distributional differences between six-member and twelve-member juries are minimal indeed, especially when we are looking at the probability of a predeliberation conviction majority of at least two-thirds. When cases are "hard" and/or jury discrimination capacities limited (i.e., p_C near .5), predeliberation verdict distributions differ considerably for different sized juries. Larger juries are more "reliable," that is, the juries of size twelve are more likely to reach the same verdict than two juries of size six, when all juries are drawn from the same juror pool and exposed to the same evidence.[11] (For a more extensive discussion of this point, see Grofman, 1974.)

Using the binomial theorem, it is straightforward to calculate the probability that, for any given p_C, any particular required verdict majority will be obtained on the first ballot. It can be shown that, regardless of p_C, some jury size and quorum rule combinations are more likely than others to give rise to a sufficient predeliberation majority to reach a verdict even before deliberations begin. For example, Saks and Ostrom (1975, pp. 170–171) note that twelve-member juries with a 9/12 quorom rule will always be less likely to have achieved a first deliberation majority sufficient to reach a verdict than will five-member juries under a 5/5 rule, regardless of p_C. Unless we know the nature of the group conformity and persuasion process in juries of different sizes and with different decision rules, we cannot conclude from the above finding that five-member juries under unanimity are less likely to deadlock—in the

[11] This is a function of the "law of large numbers" (see Feller, 1971; Zeisel, 1971). A related result applies to damages in civil cases. Zeisel (1971) points out that verdict variance (measured in monetary terms) should be less in larger sized juries; that is, the larger sized jury would be more likely to award similar damages in similar cases (see also Lempert, 1975, pp. 680–681). The same argument applies to verdict variance in general, that is, two twelve-member juries hearing the same case are more likely to reach the same verdict than two six-member juries hearing the case—where all juries are drawn from the same juror pool.

TABLE II. EXPECTED PREDELIBERATION MAJORITY AS A FUNCTION OF JURY SIZE, AND JUROR CONVICTION PROBABILITY: ONE-PARAMETER MODEL

Jury size	Predeliberation majority																	
	At least 2/3						At least 5/6						Unanimous					
6-member jury																		
P_c	.5	.6	.7	.8	.9	.95	.5	.6	.7	.8	.9	.95	.5	.6	.7	.8	.9	.95
For acquittal	.34	.18	.07	.02	.00	.00	.11	.04	.01	.00	.00	.00	.02	.00	.00	.00	.00	.00
For conviction	.34	.54	.74	.90	.98	.99+	.11	.23	.42	.66	.89	.97	.02	.05	.12	.26	.53	.73
Ratio of probability of conviction majority to probability of acquittal majority	.50	.75	.91	.98	.99+	.99+	.50	.85	.98	.99	.99+	.99+	.50	.92	.99	.99+	.99+	.99+
12-member jury																		
For acquittal	.19	.06	.01	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
For conviction	.19	.44	.72	.93	.99+	.99+	.02	.08	.25	.56	.89	.98	.00	.00	.01	.07	.28	.54
Ratio of probability of conviction majority to probability of acquittal majority	.50	.88	.99	.99+	.99+	.99+	.50	.97	.99+	.99+	.99+	.99+	.50	.96	.99+	.99+	.99+	.99+

end—than juries of twelve members operating under a 9/12 rule, a point which Saks and Ostrom (1975, p. 173) clearly recognize. Nonetheless, such a computation supports "the view . . . that a 9-of-12 standard is less stringent than 5-of-5." (Saks, 1977, p. 33).[12]

In looking at jury decision-making, it is necessary to look at both the outcome of deliberations and the process of deliberation. The U.S. Supreme Court majority in *Johnson* v. *Louisiana* (406 U.S. 356 (1972)) and *Apodaca* v. *Oregon* (406 U.S. 404 (1972) has argued that neither verdict outcomes nor the deliberative process would be significantly affected by the elimination of a jury unanimity requirement. Similarly in *Williams* v. *Florida* (399 U.S. 78 (1970)), the Court held that size reduction would not affect the deliberative process. Justice White, speaking for the five-member majority in *Johnson*, asserted,

> We have no grounds for believing majority jurors, aware of their responsibility and power over the liberty of the defendant, would simply refuse to listen to arguments presented to them in favor of acquittal, terminate discussion, and render a verdict. On the contrary, it is far more likely that a juror presenting reasoned argument in favor of acquittal would either have his arguments answered or would carry enough jurors with him to prevent conviction.

Justice Douglas, speaking for three of the minority in *Johnson*, rebutted these sanguine observations.

> As soon as the requisite majority is obtained, further consideration is not required . . . even though dissident jurors might, if given the chance, be able to convince the majority. . . . It is said that there is not evidence that majority jurors will refuse to listen to dissenters whose votes are unneeded for conviction. Yet human experience teaches that polite academic conversation is not substitute for the earnest and robust argument necessary to reach unanimity.

[12]The Louisiana law whose constitutionality was challenged in *Johnson* v. *Louisiana* involved covarying levels of size and jury quorum rule. In Louisiana, capital crimes are tried before twelve-man unanimous juries (in Louisiana, until its recent nullification by judicial review, the law required that women be excluded from jury service unless they specifically requested the opportunity to serve). Serious crimes are tried before twelve-man juries where at least nine must concur on a verdict and lesser crimes are tried before five-man unanimous juries. The appellant argued that his trial by a 9-of-12 jury gave him less protection from conviction than persons tried before 12-of-12 or 5-of-5 juries, the 9-of-12, he asserted being the easiest rule to obtain a conviction.

The Court's answer to this argument was:

> [T]he State does make conviction more difficult by requiring the assent of all 12 jurors. Appellant might well have been ultimately acquitted had he committed a capital offense. But . . . the State may treat capital offenders differently without violating the Constitutional rights of those charged with lesser crimes. As to the crimes triable by a five-man jury, if appellant's position is that it is easier to convince nine of 12 jurors than to convince all of five, he is simply challenging the judgment of the Louisiana legislature. (Saks, 1977, pp. 32, 35, note 5, with citation from majority opinion in *Johnson* v. *Louisiana* 406 U.S. 356.)

We do not know the reasons Justice White may have had for believing that a reduction in unanimity requirements would not affect minority representation in deliberation. We believe, however, that he was quite wrong. Available evidence suggests that jurors under nonunamity conditions do not deliberate until a full consensus is reached. In three-person, five-person, and six-person mock juries, groups assigned nonunanimous decision rules deliberated on average for a somewhat shorter time period than similar sized juries under a unanimity condition (Grofman,1980a; Nemeth,1976b; Padawer-Singer and Barton,1975). Only in twelve-person juries (12–0 vs. 10–2) was there mixed evidence (cf. Padawer-Singer and Barton, 1975; Saks, 1977, p. 93). However, we might expect nonunanimity rules to have a greater impact in smaller juries.

We can use the one-parameter model of jury decision-making to shed light on this issue by reinterpreting the numbers in Table II by collapsing the conviction and acquittal categories to give us the percentage of juries which can be expected to begin deliberations with accord sufficient to reach a verdict under 2/3, 5/6, and unanimity quorum rule conditions in six-person and twelve-person juries. When juries are allowed to reach nonunanimous verdicts, the probability that the jurors will have already achieved sufficient consensus for a verdict before they begin deliberations is extremely high in smaller sized juries. For example, we see from Table II that in a jury of six, even if the juror pool is evenly split in the predeliberation phase, there is a 22% probability that the jury will have a predeliberation majority of 5 or 6 and a 60% probability that the jury will have a predeliberation majority of at least 4–2. On the other hand, if the jury pool is evenly divided, the likelihood of drawing a twelve-member jury with at least nine members in agreement is only 49% and the probability of obtaining at least eight members in agreement is only 39%. However, for high levels of consensus among the jury pool, the differences between six-member and twelve-member juries virtually vanish. Indeed, for very high levels of preponderance coupled with low unanimity requirements (e.g., $p_C > .9$, unanimity requirements of 5/6 or less), larger sized juries are marginally more likely to walk into the jury room in agreement than are smaller sized juries.

The Two-Parameter Model

Several authors have rediscovered and further developed binomial trials models first investigated by such early scholars as Condorcet (1785) and Poisson (1837) to deal with the relationship between jury size and the likelihood of correct verdicts. In this section of our paper, we will confine our discussion to applications which posit an identity between the de jure quorum rule and the de facto social decision process in the jury.

One formulation is the two-parameter model analyzed at length by Gelfand and Solomon (1973, 1974, 1975, 1977) and by Grofman (1974, 1980a). In this model

$P(G)$ = a priori probability that the accused is guilty (i.e., the a priori estimate of the proportion of defendants brought to trial for offenses of that sort who are guilty).

μ =probability that a juror will not vote for an incorrect verdict.

The probability that an individual juror votes for conviction, p_C, can be expressed as

$$p_C = \mu P(G) + (1\text{-}\mu)\,(1\text{-}P(G)) \tag{23}$$

and the probability that a jury of size N will achieve exactly r votes for conviction can be expressed in terms of the binomial theorem in an expression involving N, r, μ, and $P(G)$. While μ and $P(G)$ are themselves unobservable, if the quorum rule is known they can be estimated on the basis of observable quantities such as the proportion of convictions and acquittals (see Gelfand & Solomon, 1973, 1974 for discussion of details). The data analyzed by Gelfand and Solomon (1973, 1974) are French data which were discussed by Poisson in his 1837 treatise and are for the years 1825 to 1833. In the case of criminal trials, the data are disaggregated in terms of crimes against persons and crimes against property. In the years 1825–1830, the quorum rule for criminal trials in France was 7 of 12. In the years 1831–1833, it was 8 of 12. For the first period, Gelfand and Solomon (1973) obtain estimates of $P(G) = .67$ and $\mu = .78$ for crimes against property, and $P(G) = .54$ and $\mu = .68$ for crimes against persons.[13] These estimates were obtained through several different procedures and proved remarkably robust when split-sample techniques were used.

The two-parameter model is a considerable step up in sophistication over the one-parameter model we previously discussed, in that it permits us to look at the accuracy of the juror and jury decision process. Gelfand and Solomon estimate for those French trials that there was a .998 probability that a convicted defendant was indeed guilty in the case of crimes against property and a .950 probability that a convicted defendant was indeed guilty in the case of crimes against person. If we

[13]Juries which begin evenly split are assumed eventually either to acquit or to convict (with equal probability), but never to hang.

compare these figures to their estimates for μ ($\mu = .78$ and .68, respectively) we see that the jury process represents a quite considerable improvement in accuracy over individual juror decision-making.

Using the two-parameter model, under the assumption of a decision rule of simple majority (where evenly split juries convict or acquit with equal probability) Gelfand and Solomon (1974, p. 36) find the difference in the expected conviction rate of six-member and twelve-member juries to be negligible. Furthermore, if $\mu > .5$ and $P(G) > .5$ or if $\mu < .5$ and $P(G) < .5$ (which I regard as the less plausible case) they find six-member juries marginally less likely to convict than twelve-member juries, although otherwise the reverse holds true.

THE PERSUASION AND CONFORMITY PROCESS IN JURY DELIBERATIONS

Social Decision Schemes

Consider a group (jury) of size N choosing among j (verdict) options. The number, q, of distinguishable distributions of predeliberation first choice preferences among those options is given by

$$q = \binom{N + j - 1}{N} \tag{24}$$

A social decision scheme provides a mapping from each of the

$$\binom{N + j - 1}{N}$$

predeliberation preference distributions into a probability vector of verdict outcomes. Such a social decision scheme can be represented in terms of a stochastic decision matrix, D, such that

$$\sum_j d_{ij} = 1$$

Thus, given the probability, p_i, that a randomly chosen juror prefers the ith verdict alternatives ($i = 1, 2, \ldots, j$) at the outset of interaction and a specification as to the nature of the social decision scheme which is being used, we can calculate the probability P_j of a jury deciding for the ith verdict.

Given the values of p_i, we may use the multinomial theorem to calculate the vector $\pi = (\pi_1, \pi_2, \ldots, \pi_q)$ which represents the probability of occurrence of each possible initial distribution of verdict preferences.

NUMBER OF JURORS VOTING FOR CONVICTION/JURY VERDICT	A	C	H
6	0	1	0
5	$\frac{1}{12}$	$\frac{10}{12}$	$\frac{1}{12}$
4	$\frac{2}{12}$	$\frac{8}{12}$	$\frac{2}{12}$
3	$\frac{3}{12}$	$\frac{6}{12}$	$\frac{3}{12}$
2	$\frac{8}{12}$	$\frac{2}{12}$	$\frac{2}{12}$
1	$\frac{10}{12}$	$\frac{1}{12}$	$\frac{1}{12}$
0	1	0	0

Fig. 10. Hypothetical social decision scheme for a unanimous six-member jury proposed by Gelfand and Solomon (1977).

Postmultiplying this vector by the matrix D yields the vector $P = (P_1, P_2, \ldots, P_j)$ of expected verdict outcomes.[14]

Our perhaps confusing abstract presentation of the formal structure of social decision schemes can, we hope, be clarified by a simple example. Let $N = 6$, $j = 3$ (C = convict, A = acquit, H = hang). We show in Figure 10 a social decision matrix D for the case of a six-member jury which has been proposed by Gelfand and Solomon (1977).

For specified p_C, we may use the binomial theorem to calculate the probability vector, π, of the seven distinguishable predeliberation verdict distributions 0–6, 1–5, . . ., 6–0, where the first number represents the number of guilty votes (see our discussion of the one-parameter model above). Thus, for example, if $p_C = .6$, than $p(0\text{–}6) = (.6)^0\,(.4)^6 = .004$.

Hence for specified p_C we can calculate an expected distribution of

[14]One form of decision matrix of particular interest is that which represents a K/N social decision scheme, that is, a social decision scheme in which a majority of at least K of N voters holding a particular verdict preference is sufficient to guarantee that that verdict will become the jury choice. Such a social decision matrix will consist only of zeros and ones.

Grofman (1974, 1976a) has looked at jury decision-making under the assumption of a K/N effective decision rule, where K is the number of votes which is (de facto) necessary for conviction and where N is jury size. Using data on twelve-member (unanimous verdict) criminal trials in New York City in 1971 and 1972, Grofman (1976b) finds an 8/12 model to offer the best, but still rather unsatisfactory, fit. Fitting the unanimity model to this New York City data leads to parameter estimates of $P(G) = 0.64$, $\mu = 0.996$. Thus, the unanimity model is seen to require an absurdly high mean juror discrimination capacity, and this provides us with reason for rejecting it in favor of some form of social decision scheme with a sizeable majoritarian component.

verdict outcomes resulting from this social decision scheme using the rule

$$P = \pi D \tag{25}$$

The scheme described in Figure 10 involves considerable elements of social conformity and persuasion, since even when the jury does not begin unanimous it almost invariably ends up so. There is considerable evidence that when, prior to the jury deliberations, a majority of the jury is in accord as to the verdict, the likelihood is very high that the deliberations will give rise to a unanimous verdict with the outcome congruent with the views of the initial majority. Presumably the majority persuade (or otherwise browbeat) the minority. In one study of twelve-member juries, 93% of the verdicts accorded with the views of the initial majority, 4% of the juries remained hung, and in only 3% of the cases did the minority persuade the majority (Broeder, 1959). Thus, the effect of the group conformity process which appears to operate in juries is to exaggerate the impact of the initial majority in the direction of a unanimous verdict consistent with their views.

The assertion that the size of the predeliberation majority largely serves to determine verdict outcome is supported by several other studies (Davis, 1973; Davis, Kerr, Atkin, Holt, & Meek, 1975, Davis, Kerr, Stasser, Meek, & Holt, 1975; Grofman, 1980a ; Nemeth, 1976a; Saks, 1977).[15] In American criminal trials the percentage of hung juries is quite low; for example, less than 5% in New York City's Supreme Court in the 1960s (Grofman, 1976a). This suggests a large portion of "open and shut" cases. However, when individual jurors have some probability of changing their verdict in the direction of the majority consensus, it is not necessary for the jury to begin virtually unanimous to wind up unanimous most of the time. For example, in juries of size twelve, to obtain a percentage of hung jurors of 5%, we need postulate only a .75 average initial concordance if the jury decision process is a simple conformity to the majority (7/12) rule or a .83 initial concordance if the jury conformity and persuasion process can be described by a two-thirds (8/12) rule.

An important and unresolved issue, however, is whether it is the absolute number of jurors in the minority that is crucial, or whether it is the relative proportions of the minority and majority factions which determine minority resistance to majority persuasion. Some authors (e.g., Lempert, 1975; Zeisel, 1972) have strongly argued for the former view. They cite the classic Asch (1956) conformity experiments which

[15]There are a number of other jury studies we might have cited, but many of them are severely marred by methodological flaws. See Grofman (1977b, 1977c), Diamond (1974), Zeisel and Diamond, (1974), and Saks (1977) for critical reviews.

suggest that a single individual supporting one's position is sufficient to harden an individual in support of his initial view and buttress him or her against majority persuasive efforts, regardless of the size of the majority. We do not find the Asch (1956) experiments to be definitive, since the jury setting is one of sustained pressure and persuasion and the extent of observed change in minority views in the direction of majority sentiment in the group is considerably greater than that found in the Asch line-estimation experiments. We believe that the available evidence from six-person and twelve-person juries and mock juries offers inadequate data for a definitive specification of the relationship between predeliberation preferences and expected final verdict and thus renders impossible a definitive judgment of the numbers versus relative proportions controversy. Our reading of the limited evidence, however, argues in favor of the proportionality thesis.

Kalven and Zeisel, the authors of the classic study of jury decision-making (Kalven & Zeisel, 1966, p. 462), assert that "[I]t requires a massive minority of four to five jurors (out of 12) at the first vote to develop the likelihood of a hung jury." Their findings suggest that in juries of twelve, a predeliberation majority of 11–1 (1–11) will go to unanimity with virtual certainty, and a predeliberation majority of 10–2 (2–10) will go to unanimity with lower (but still quite high) probabilities.

The most realistic and extensive (92 trials) mock jury study (Padawer-Singer & Barton, 1975) had very similar findings for twelve-member juries: no hung juries with fewer than three members on the predeliberation minority (8 of 10 hung juries with 4–5 members in the minority, 1 of 10 with an evenly split jury). For six-member juries they found no hung juries with fewer than 2 members in the predeliberation minority (3 of 4 hung juries occurring with 2 members in the minority, 1 of 4 with an evenly split jury). Furthermore, for six-member juries, they found no reversal of the initial majority occurred unless the predeliberation majority was at least four while for six-member juries they found no reversal of the initial majority occurred unless the initial majority was at least two in number.

Davis, Kerr, Stasser, Meek, and Holt (1975) studied the decision-making of mock juries of six and twelve members assigned either a two-thirds or a majority decision rule. They found that neither the jury size nor the assigned decision rule created a significant overall impact on the distribution of jury verdicts. They also found that the rule which best predicted overall jury verdicts as a function of predeliberation consensus was a simple two-thirds rule—which was the best predictor under all four experimental conditions.

In another study, which was confined to six-member juries, Davis, Kerr, Atkin, Holt, and Meek (1975) found a (modified) two-thirds rule to be the best predictor of the relationship between predeliberation consensus and final ballot verdict—a rule in which jurors always eventually voted in accordance with the views of a two-thirds predeliberation majority, but did not always hang if no two-thirds predeliberation majority existed. Similar results for three-person and five-person juries were found by Grofman (1980a).

Both of the studies by Davis *et al.* (1975, 1975) and also those of Grofman (1980a) and Nemeth (1976b)used college students as jurors; all four studies also deviated from real jury deliberations in other ways, for example, by only permitting a maximum of one hour of jury deliberation time. Also, the Davis, Kerr, Stasser, Meek, and Holt study (1975) involved a case rather heavily biased toward acquittal. Thus, we believe it useful to be cautious in extrapolating from these findings to "real" jury behavior (cf. Zeisel & Diamond, 1974, p. 291, note 47; Bray & Struckman-Johnson, 1976).

Two other studies (Davis, 1973; Saks, 1977), each of which makes use of jurors drawn from an actual jury pool, provide support for a social decision scheme model first proposed by Davis (1973), which is considerably more complex than a simple two-thirds decision rule.

Davis (1973) reanalyzed the data from Simon (1967), which had been collected from twelve-member mock juries drawn from local jury pools in three different jurisdictions: Minneapolis, St. Louis, and Chicago. Her juries were exposed to edited tape recordings of transcripts of trials involving housebreaking (30 juries) or incest (68 juries). In Table III we show the relative frequency of verdicts both for indi-

TABLE III. DECISIONS BY MOCK JURIES AND INDIVIDUALS IN SIMON (1967) HOUSEBREAKING AND INCEST CASES AND PREDICTIONS FROM VARIOUS DECISION-RULE MODELS

	Housebreaking case			Incest case		
	P_C	P_A	P_H	P_C	P_A	P_H
Individual decisions	34%	66%		67%	33%	
Jury decisions	27%	56%	17%	71%	13%	16%
7/12 rule	7%	80%	13%	81%	5%	14%
8/12 rule	3%	61%	36%	64%	4%	32%
11/12 rule	0%	5%	95%	4%	0%	95%
Unanimity rule	0%	1%	99%	1%	0%	99%
Davis (1973) model	22%	62%	16%	66%	18%	16%

[a] Data drawn in part from Davis (1973, Table 4); housebreaking case, $N = 68$; incest case, $N = 30$.

vidual jurors and for juries for the Simon (1967) data along with the fit of various rules of the *K*/12 type and the fit of the social decision scheme proposed by Davis (1973) previously specified in Figure 11. As we see, Davis's scheme fits the data better than any rule of the *K*/12 type, although the fit is far from perfect. However, the fit of an 8/12 rule is also not unreasonable.

Saks (1977) ran a series of experiments using a videotaped trial involving role playing by law-related professionals with considerable courtroom experience; these professionals were allowed to play their roles extemporaneously based on the facts of the case provided them from an outline. The defendant in this trial was played by an actor and the final witness was played by a person with appropriate background characteristics for that part. We present in Table IV a portion of Saks's (1977) experimental data drawn from a study which made use of former jurors from the Franklin County (Ohio) state courts in twelve-member mock juries under a unanimity quorum rule condition. As we see from Table IV, Davis's (1973) model provided a quite good fit to Saks's (1977)

NUMBER OF JURIES VOTING FOR CONVICTION/JURY VERDICT	A	C	H
12	0	1	0
11	0	1	0
10	$\frac{2}{24}$	$\frac{20}{24}$	$\frac{2}{24}$
9	$\frac{3}{24}$	$\frac{18}{24}$	$\frac{3}{24}$
8	$\frac{4}{24}$	$\frac{16}{24}$	$\frac{4}{24}$
7	$\frac{5}{24}$	$\frac{14}{24}$	$\frac{5}{24}$
6	$\frac{6}{24}$	$\frac{12}{24}$	$\frac{6}{24}$
5	$\frac{14}{24}$	$\frac{5}{24}$	$\frac{5}{24}$
4	$\frac{16}{24}$	$\frac{4}{24}$	$\frac{4}{24}$
3	$\frac{18}{24}$	$\frac{3}{24}$	$\frac{3}{24}$
2	$\frac{20}{24}$	$\frac{2}{24}$	$\frac{2}{24}$
1	1	0	0
0	1	0	0

Fig. 11. Social decision scheme for a unanimous twelve-member jury proposed by Davis (1973).

TABLE IV. DECISIONS BY MOCK JURIES IN SAKS (1977) BURGLARY CASE, EXPERIMENT II, AND PREDICTIONS FROM VARIOUS DECISION-RULE MODELS[a]

	p_C	p_A	p_H
Jury decisions	60%	20%	20%
7/12 rule	68%	14%	17%
8/12 rule	46%	5%	49%
11/12 rule	2%	0%	98%
Unanimity rule	0%	0%	99+%
Davis (1973) model	58%	24%	18%

[a]Data are drawn from Saks (1977, Table 4-14, p. 99); $N = 10$.

data, and a considerably better fit than that of any decision rules of the K/12 type, although the 7/12 rule also offers a reasonable fit to the data.[16]

One finding of all the empirical studies is quite clear: the social decision scheme operative in juries is nowhere near as simple as the apparent (de jure) quorum rule would have made it appear. Indeed, there is some evidence (albeit drawn from groups other than juries) that many group-decision processes operate on two levels. On one level, there is a requirement for unanimity concerning a particular decision. On the other level, there is a unanimous or near unanimous commitment to adopt a form of majoritarian decision procedure as a means of resolving deadlock. Thus juries may be both unanimous and majoritarian at the same time (see Davis, Kerr, Sussman, & Rissman, 1974, pp. 265–268).

Looking at those various studies in toto, we believe that the evidence is also clear that if there are only two members in the minority in a twelve member jury, those two are likely to be persuaded by or conform to the views of the majority. Thus we believe that the conformity and persuasion process within a jury, at least within a jury of twelve members, is unlike that observed by Asch (1956) in his line-estimation experiments, and extrapolations to the jury case based on Asch's findings should be regarded as quite suspect.

[16]Grofman (1976a) has proposed a social decision scheme for the Simon (1967) data which is based on a power function model. We shall not bother to specify that model here. The interested reader is referred to Grofman (1976a) for a discussion of the model and its historical antecedents. Saks (1977) also has proposed a power function model for his data, but provides no exact details.

The social decision schemes we have presented were largely based on analyses of juries operating under a quorum requirement of unanimity. A natural question to ask is "Does a change in the explicit (quorum) rule change the implicit rule?" (Saks, 1977, p. 101). The evidence on this point is limited. Some studies (e.g., Davis, Kerr, Stasser, Meek, & Holt, 1975) suggest an answer to this question in the negative; on the other hand, Saks (1977, p. 101) offers the very tentative suggestion based on a careful but inconclusive comparison of his experiments under unanimous and nonunanimous quorum requirements, that "reducing the explicit (quorum rule) does also reduce the implicit decision rules juries operate by."

Nonetheless, because of the social decision process which has been observed to operate in jury decision-making, it is very likely that shifts from unanimous to nonunanimous verdicts will have relatively minimal impact on verdict outcomes as long as jury size is held constant (cf. Grofman, 1976a). Of course, in the area of jury decision-making very small differences may be particularly important.

> There are at least three reasons for this last point. The first is that the base is very high. If there are 100,000 jury trials a year, a 2% difference in outcomes is 2,000 cases. The second is that those cases in which differences occur may occupy a peculiar position, given the reasons why we have jury trials. If cases of the sort that would be affected by decision rule did not exist in the system, there might be good reason to abolish the right to jury trial altogether, or to develop a system involving lay jurors deliberating along with judges. Third is that there may be a peculiar value in even a single case in an area as value infused as the law. In other words, even one innocent defendant sentenced to death because of a change in jury size or decision rule might be too many. (Lempert, personal communication, August 27, 1976; see also Lempert, 1975)

Of course some decision-rule effects will occur even in a near-majoritarian social decision scheme such as proposed by Davis (1973); for example, in that scheme, if unanimity requirements are lowered to 10 of 12, there will no longer be any expectation of a two-member minority succeeding in hanging the jury or in reversing the views of the majority. Moreover, Asch's (1956) results do suggest that "although situations in which 2 of 12 hang a jury are rare . . . they are not as rare as situations in which 1 of 6 hangs a jury" (Lempert, personal communication, August 27, 1976). Thus, we might expect a greater impact of reduction in decision rule for juries of six than for juries of twelve. Furthermore, in close cases, decision rule can be expected to have a considerably greater effect than in clear cases, since the latter give rise to a much higher probability of a predeliberation split than those in which the verdict is a foregone conclusion.

Limitations of the Social Decision Scheme Approach

There are a number of important limitations to the social decision scheme approach, at least in its present stage of development. First,

> [S]ocial decision scheme theory is indifferent to the important question of whether a member changes his preference as a function of discussion (either during or after decision), or merely acquiesces or does some of both. This is an empirical question that should be met by experimental estimates, not assumptions, and the answers surely differ with social context and task (motivation, personal investment, etc.). (Davis, *et al.* 1974, p. 269)

In the Davis *et al.* (1974) study, the postdiscussion personal opinions of group members were, on the average, between their original preference and the decision of the group in which they had participated. This suggests that what is happening in jury deliberation involves elements both of persuasion and of (temporary) conformity. Clearly, as Davis *et al.* (1974) suggest, this question needs further study. For a useful discussion of some experimental results bearing on this issue (most, however, not involving mock juries) see Myers and Lamm (1976).

Second, another major difficulty with the usual social decision scheme models is that they assume that the truth or falsity of a view is irrelevant to its probability of being adopted when we control for the size of the group who are its advocates. This contradicts our intuitive feeling that truth should have a better chance of prevailing than falsehood—not just at the level of individual judgment, and not just in terms of the predeliberation preferences of the group, but also in terms of the actual deliberative process. Those who have the better arguments should, it would seem, have a better chance to prevail in the cause of group discussion and argument. This issue has been investigated by Laughlin, Kerr, Munch, and Haggarth (1976). In one problem-solving task, truth always wins, that is, if any one member of a four-person group knows the correct answer, that answer becomes the group choice. However, in another problem-solving task also involving four-member groups, truth wins for sure only if its advocates number 3 or 4; if its advocates number 2 then truth is more likely to prevail than not, but if the correct view has only one advocate, then that individual often bows to majority pressure.

A third important limitation of the social decision scheme approach to jury decision-making is that its models are static ones; that is, they only look at the end state of jury deliberation and provide no consideration of the dynamics of the process wherein jurors shift from their predeliberation preferences. It would clearly be desirable to have such dynamic models. A natural way to model jury-decision processes over time is in the form of a finite state Markov chain, where each state is a different distribution of jury preferences and where successive stages of the process can be regarded as providing us outcomes of successive stages of jury balloting (for an elementary introduction to Markov chain theory, see Kemeny, Snell, & Thompson, 1972).

Although some interesting work in the development of Markov chain models of jury conformity processes has been done (Klevorick & Rothschild, 1979; Grofman, 1978b), to discuss this work in any detail would require a substantial digression into the mathematical properties of Markov chains and so we shall simply note for the more technically sophisticated readers that Klevorick and Rothschild's work involves a model which can be thought of as a reverse Ehrenfest diffusion model (see Feller, 1971), while Grofman has adapted for the jury context a differential equation model of conformity behavior developed by Coleman (1964, Chap. 13), which is also a form of Polya urn model (see Feller, 1971; see also Cohen, 1963; Cohen & Lee, 1975).

JURY DECISION-MAKING, JURY SIZE, AND NOTIONS OF JUSTICE

Supreme Court rulings allowing for reduced jury size and less than unanimous decisions have generated considerable outcry from constitutional scholars and civil libertarians who have expressed concern that the rulings may lead to an increased probability that defendants who are innocent will be wrongly convicted (see, e.g., *New York Times* Editorial May 25, 1972; Saari, 1973; Zeisel, 1971, 1972).

Gelfand and Solomon (1977) have used the two-parameter model of juror decision-making discussed in the Multiple Verdict Options Section above (p. 317) and combined it with the social decision schemes given in Figure 10 (for a six-member jury) and a modified version of that given in Figure 11 (for a twelve-member jury) to generate a comparison of the expected accuracy of six-member and twelve-member juries. We show their proposed social decision scheme for a twelve-member jury in Figure 12. Entries which represent changes from the scheme in Figure 11 are circled.

Gelfand and Solomon (1974) sought to find values of μ and $P(G)$ which are consistent with data given in Kalven and Zeisel (1966, p. 488) on 225 twelve-member jury outcomes and first ballot verdict distribution. They considered three different estimating procedures, all of which give estimates: $P(G) \approx .7$ and $\mu \approx .9$. They obtained maximum likelihood estimates of $\mu = .88$ and $P(G) = .69$. While these values for six-

Number of jurors voting for conviction/jury verdict	A	C	H
12	0	1	0
11	0	1	0
10	(2/24)	20/24	(2/24)
9	(3/24)	18/24	(3/24)
8	4/24	16/24	3/24
7	5/24	14/24	5/24
6	6/24	12/24	6/24
5	14/24	5/24	5/24
4	16/24	4/24	4/24
3	18/24	3/24	3/24
2	24/24	(2/24)	(2/24)
1	1	0	0
0	1	0	0

Fig. 12. Modified social decision scheme for a unanimous twelve-member jury proposed by Gelfand and Solomon (1977). Circled items reflect differences from the social decision scheme shown in Figure 11.

member and twelve-member juries operating under the hypothesized social decision schemes do not provide a perfect fit to the observable parameter values for the Kalven and Zeisel data, for which $P_C = .642$, $P_A = .303$, and $P_H = .06$, the fit for twelve-member juries is nearly perfect and the fit for the six-member jury appears quite good, given that we would anticipate a lower percentage of hung juries in six-member juries than in twelve-member juries.[17] The Gelfand and Solomon (1977) maximum likelihood estimates for both observable parameter values (P_C, P_A, and P_H) and quantities which are unobservable ($P_{G|C}$, $P_{I|A}$, $P_{I|C}$, and $P_{G|A}$) are shown in Table V.

Table V reveals what might be regarded as quite striking disparity in

[17]Since the Kalven and Zeisel (1966) data represent first-ballot preferences, they should understimate the extent of majority conformity and persuasion since some minority members may have changed from their predeliberation preferences by the time of the first ballot. This problem appears not to have been noticed by Gelfand and Solomon (1977).

TABLE V. A COMPARISON OF SIX-MEMBER AND TWELVE-MEMBER JURIES OPERATING UNDER THE SOCIAL DECISION SCHEMES GIVEN IN FIGURE 10 AND FIGURE 12, RESPECTIVELY[a]

	P_C	P_A	P_H	$P_{G\|C}$	$P_{I\|A}$	$P_{I\|C}$	$P_{G\|A}$
Six-member juries	.635	.321	.045	.968	.861	.033	.150
Twelve-member juries	.637	.303	.060	.978	.939	.022	.062

[a]Taken from Gelfand and Solomon (1977).

outcomes between six-member and twelve-member juries. Although six-member juries are actually shown as marginally less likely to convict than twelve-member juries, "using a six-member jury in place of twelve, one-and-a-half times as many innocent defendants will be convicted and twice as many guilty defendants will be acquitted" (Gelfand & Solomon, 1977, p. 220). A more precise way of stating the Gelfand and Solomon (1977) findings on the relative accuracy of six-member and twelve-members juries is to say that the probability of someone who has been convicted actually being innocent, $P_{I|C}$, is slightly more than 3% for six-member juries compared to slightly more than 2% for twelve-member juries, while the probability of someone who is acquitted actually being guilty is roughly 14% for six-member juries and only 6% for twelve-member juries. Thus, under the Gelfand and Solomon (1977) assumptions, changing from twelve-member to six-member juries is a double blow to justice: it will convict one additional innocent defendant per every hundred defendants convicted and it will acquit eight additional guilty defendants for every hundred defendants acquitted. Basing their findings primarily on the results of this modeling, Gelfand and Solomon (1977, p. 205) conclude that "the 12-member jury is to be preferred to the 6-member jury."

While we share these authors' substantive conclusion, and while we regard the work of Gelfand and Solomon (particularly that in their 1977 article) as representing the most sophisticated analysis of jury decision-making now available, we wish to insert a note of caution in interpreting their results. Intuition would suggest that the larger the jury size, *ceteris paribus*, the less likely is conviction. Such intuition may or may not be correct (cf. Table I vs. Table V). Intuition would also suggest that the larger the jury size, the lower the probability of a Type I error, that is convicting the innocent. The problem is, of course, the *ceteris paribus* assumption. Only if we know the form of the relationship between predeliberation consensus and verdict, can we evaluate the implications of jury size differences for verdict accuracy.[18] The extent to which differences will be predicted will depend both on the nature of the underlying group conformity and persuasion process postulated and on the extent of predeliberation accord as to verdict found in the juror pool. This predeliberation accord, in turn, will, in the two-parameter model, be a function of μ and $P(G)$. The assumptions made by Gelfand and Solomon (1974, 1977) as to μ and $P(G)$ are, we believe, quite reasonable ones. Similarly, we believe their hypothesized social decision scheme for twelve-member juries to be a reasonable one; it is virtually identical to one proposed by Davis (1973) which has had fair empirical support (see discussion above). On the other hand, their hypothesized social decision scheme for six-member juries is, in our view, highly suspect. Unlike the scheme for twelve-member juries, the six-member scheme they offer has had no previous empirical test and while it correctly reflects limited available evidence for a sizable majoritarian component, it also has characteristics which we believe to be counterfactual. The Gelfand and Solomon (1977) social decision scheme (see Figure 10) exhibits a relationship between size of predeliberation minority and expected final verdict which is identical for proconviction and proacquittal minorities, except for an initially evenly divided jury which exhibits a proconviction bias. We are suspicious both of the symmetry assumption and of the assumption of a proconviction bias in juries which begin evenly divided.

Recent studies of six-member juries cast doubt on a symmetric relationship between size of predeliberation minority and expected final verdict with respect to proacquittal and proconviction minorities. Nemeth (1976) used a juror assignment process to hold constant the size of the majority at exactly 4 out of 6. Under a unanimous rule condition, when the majority was for acquittal, the verdict in those juries which reached a verdict (8 of 9) was acquittal 100% of the time; when the majority was for conviction, the verdict was guilty in only 60% of the juries (5 of 10) that reached a verdict. Thus, when the majority was for acquittal only one jury out of nine hung; when the majority was for

[18]Of course, the social decision scheme which characterizes jury behavior need not be invariant with respect to type of case, nor need the demographic characteristics of the jurors be irrelevant—it may well matter which juror(s) are in the minority and which in the majority. Gelfand and Solomon (1977) are, in effect, averaging over type of case to produce a social decision scheme for the aggregate data being analyzed. A similar strategy has been pursued by Grofman(1974,1980a). Neither Davis (1973) nor Grofman (1974, 1976a, 1977a, 1980a), nor Gelfand and Solomon (1977) attempted to incorporate characteristics of the jury minority other than their number into a social decision scheme; although other authors who have not made use of formal decision models have dealt with personality and demographic characteristics of jurors as they relate to juror persuasibility (see discussion of this point in Davis *et al.*, 1977).

conviction five juries out of ten hung. Davis *et al.* (1975a) also found proacquittal majorities somewhat more likely to prevail than proconviction majorities (30 out of 34).[19] The assumption of proconviction bias in evenly split six-member juries also has, as far as we are aware, no empirical support. On the contrary, Davis *et al.* (1975a) find a strong proacquittal bias in such juries: 68% acquit, 16% convict, and 16% hang ($N = 21$).[20] Thus, the comparison of expected judgmental accuracy of six-member versus twelve-member juries made by Gelfand and Solomon (1977) rests on a series of assumptions, some of which we believe to be shaky.

For some alternative assumptions as to the nature of the social decision scheme in six-member juries, we can show the six-member jury to be superior in judgmental accuracy to the twelve-member jury. Let us assume a simple majority rule social decision scheme where evenly split juries are as likely to convict as to acquit, and never hang. We may use previous estimates of μ and $P(G)$ to obtain the relevant parameter estimates for such a social decision scheme. These values (drawn from Gelfand & Solomon, 1977) are shown in Table VI for both six-member and twelve-member juries.

If we hypothesize that six-member juries operate under a simple majority social decision scheme while twelve-member juries operate under the social decision scheme shown in Figure 11 (and hence if we compare Row 1 in Table VI with Row 2 in Table V), we find six-member juries to be clearly superior in judgmental accuracy to twelve-member juries. Under these assumptions, six-member juries wrongfully convict only six defendants per thousand compared to two defendants per hundred for twelve-member juries. Similarly, six-member juries wrongfully acquit only three defendants per hundred as compared to six defendants per hundred for twelve-member juries. Of course, simple majority rule is not an empirically correct model for the decision process of either six-member or twelve-member juries. Nonetheless, it should be

[19]Symmetry in verdict impact between proconviction and proacquittal minorities may also be an erroneous assumption for twelve-member juries. Professor Allen Barton (personal communication, 1975) has pointed out that in the Kalven and Zeisel (1966) data "the 'lone holdout' on the last ballot of hung juries is invariably against conviction and ... only 12% have minorities of three or less for conviction, while 44% of hung juries have minorities of three or less for acquittal. This suggests that 'unanimous' not guilty verdicts are sometimes the result of one, two or three pro-conviction jurors simply giving in without being convinced, rather than insisting on hanging the jury." Barton goes on to suggest that "we probably have a system of unanimity for conviction, but of acquittal by a 9 to 3 majority or better."

[20]Kalven and Zeisel (1966) found evenly split twelve-member juries exactly as likely to acquit as to convict.

TABLE VI. A COMPARISON OF SIX-MEMBER AND TWELVE-MEMBER JURIES FOR THE SIMPLE MAJORITY DECISION SCHEME[a]

	P_C	P_A	P_H	$P_{G\|C}$	$P_{I\|A}$	$P_{I\|C}$	$P_{G\|A}$
Six-member juries	.684	.316	0	.994	.970	.0060	.0305
Twelve-member juries	.690	.310	0	.999+	.999	.0003	.0016

[a] Taken from Gelfand and Solomon (1977, Table 4, p. 217).

clear from this example that the superiority of twelve-member to six-member juries is very sensitive to the assumptions used as to the nature of the social decision scheme in each. Other, more plausible, assumptions as to the nature of the social decision scheme in the six-member jury may lead to a different conclusion as to the relative judgmental accuracy of juries of six and juries of twelve than that reached by Gelfand and Solomon (1977). More generally, it is possible to show that the group judgmental accuracy will rise the closer its social decision scheme comes to pure majority rule (Grofman, 1974, 1980a). Thus, if the social decision scheme in smaller juries more closely approximates simple majority rule than that in larger juries, we would expect that the smaller juries would, somewhat counterintuitively, actually be less likely to err than the larger juries.[21]

The Gelfand and Solomon (1977) findings for the two-parameter model also have important implications which these authors seem unaware of; to wit, if we wish to improve jury judgmental accuracy, we should eliminate jury deliberation and replace it with a simple majoritarian decision rule based on jurors' predeliberation preferences. If we allow juries to deliberate, the social decision scheme used by juries which deliberate will, according to the Gelfand and Solomon (1977) model, substantially increase the probability of Type I and Type II error for juries both of six and twelve members, as compared to decisions reached by the same sized juries which decide verdicts by simple majority preference aggregation process with no deliberation (Klevorick, personal communication, 1978). Advocates of twelve-member juries who find the Gelfand and Solomon (1977) results appealing and who wish

[21] If both twelve-member and six-member juries use a simple majoritarian social decision scheme, then twelve-member juries are clearly superior in judgmental accuracy, as we see from comparing rows 1 and 2 of Table VI. We might also wish to introduce the additional complication of differentially weighting Type I and Type II errors. Thus, if smaller juries were more acquittal-prone than larger ones in certain equivocal cases (e.g., juries which begin evenly split), it might be the case that the smaller juries would have a lower value for $P_{I|C}$ even though a higher value for $P_{G|A}$.

to cite them in support of retention of the present jury system would do well to consider the fact that the clearest policy implication of the Gelfand and Solomon (1977) modeling efforts is the finding that jury deliberation impairs justice—a finding which could be used to argue for drastic change in the present jury system: the elimination of jury deliberation and the adoption of simple majority verdicts.[22]

Gelfand and Solomon (1974) have also fitted the two-parameter model to Kalven and Zeisel's (1966) data under the assumption of a social decision scheme of an 8/12 type, and compared those results with their earlier (1973) findings on criminal trials in France in the 1830's. They found overall values of $P(G) = 0.64$ and $\mu = 0.75$ for the French data and $P(G) = 0.70$ and $\mu = 0.90$ for the U.S. data. Thus, the success of the American criminal justice system in weeding out innocents prior to trial appears only somewhat better than that of the French criminal justice system of over a century ago; however, American jurors appear to be more "discriminating" than their French counterparts of last century. Of course, as Gelfand and Solomon (1974, p. 36) point out, "more analysis and interpretation would be required before one could place strong faith in these conclusions."

Using the two-parameter model, Grofman (1974, 1980a) has examined the consequences of varying jury size and "effective" majority requirements in terms of a criterion parameter which is used to differentially weigh the desirability of "convicting the guilty" and "freeing the innocent." Grofman (1974) shows that unanimity may be desirable as the effective decision rule even for cases where "convicting the guilty" is regarded as more desirable than "freeing the innocent," provided mean juror discrimination capability is low and/or the pretrial screening process is extremely ineffective in "weeding out" the innocent. Grofman (1978a) has also shown that, for jurors who would be willing to see as many as R defendants set free rather than allow one

[22]While the evidence is mixed, when groups must make subjective probability judgments, there do appear to be benefits from group interaction above and beyond the statistical effect of pooling individual contributions which is all that the social decision scheme approach in its present form can capture. Gustafson, Shukla, Delbecq, and Halster (1973) compared three processes of pooling information to obtain subjective likelihoods with the accuracy of individual likelihoods estimates. They found an "Estimate–Talk–Estimate" process superior in approaching accuracy to estimates or to groups using "Talk-Estimate" (interacting group) or "Estimate-Feedback-Estimate" (an approximation to a Delphi group) procedures. One possible implication of this finding for jury decision-making is that juries should begin with a straw ballot prior to discussion and should then discuss the reasons for their votes. On the other hand, it might be argued that having to report their verdicts would commit subjects to their own predeliberation decisions and thus increase the incidence of hung juries.

innocent person to be convicted, the social decision rule which minimizes expected juror disappointment in the jury verdict outcome is an $R/(R + 1)$ rule.[23]

Gelfand and Solomon (1974, 1975) and Grofman (1974) have each independently proposed a three-parameter model where $P(G)$ is as before but where instead of μ we have two parameters.

μ_1 = probability that a juror will find a guilty defendant guilty
μ_2 = probability that a juror will find an innocent defendant innocent

Gelfand and Solomon (1974) fit this model to data drawn fron Kalven and Zeisel (1966) previously analyzed via the two-paramete model and find $P_G = 0.66$, $\mu_1 = 0.90$, and $\mu_2 = 0.92$. Comparing these values to their previous findings of $P(G) = .70$, $\mu = .90$, they conclude that the three-parameter model offers little improvement over the two-parameter model, given the fact that μ_1 and μ_2 do not appear to diffe much for the juror population under investigation. Alternative techniques for parameter estimations for this model, developed in Gelfanc and Solomon (1975), lead them to reaffirm this conclusion.[24]

CONCLUDING REMARKS

If we wish to optimally represent the majority sentiment of the poo of potential jurors we may easily show (Auchmuty & Grofman, 1972 that we wish juries to operate under simple majority rule and we wisl them to be as large as possible. However, as one leading scholar has pu it (Barton, Personal Communication, 1975), "the policy question i whether that is what we want jurors to do, and if so how much mone we want to spend achieving this result, since from this viewpoint 24 i better than 12 and 48 than 24." The issue of how to resolve conflictin arguments for or against particular jury sizes or decision rules is not a easy one. We can do no better than to quote at some length the views c another leading scholar who has written both eloquently and intelligently on this question:

[23]For $R/(R + 1)$ noninteger, we take the upper integer bound.

[24]Parallel to this work on jury decision-making has been work by scholars in the publ choice area on very similar models and related (although somewhat more general) que tions (Badger, 1972; Curtis, 1972; Grofman, 1975b, 1980a; Kazmann, 1973; Niemi & Wei berg, 1972; Rae, 1969; Schofield, 1971, 1972; Taylor, 1969).

> "[I]f twelve are better than six, why not choose twenty-four?" (Grofman, 1976). There might be social-psychological answers to this question (e.g., coordination problems or the dominance of leaders might be such that twelve could be better than six because it is larger and better than twenty-four because it is smaller) but I think there is a more fundamental answer which has to do with popular psychology and the acceptance of tradition. Twelve by some standard seems fair (it is the accepted operationalization of the proper trade-off between economics of scale and mistaken verdicts, if you will). While twenty-four might do even better given the values that juries are supposed to promote, we as a people are not going to worry about this, absent clear evidence that twelve is failing miserably in delivering justice at an acceptable cost. Each generation does not have to decide for itself whether its institutions are delivering the optimum quantity of valued results. Six, by being a deviation from tradition suggests that we may be changing our judgments as to what the proper trade-offs in the area of delivering justice are. . . . Then, even small numbers may become important—if only to force those arguing for change to show that the benefits of change outweigh real costs. (Lempert, Personal Communication, August 27, 1976; see also Lempert, 1975)

On the basis of the limited available evidence, we believe it to be true, contra the U.S. Supreme Court, that jury size can make a "discernible" difference. Admittedly, the technical and methodological problems in arriving at reasonable jury decision-making models and reasonable parameter estimates for those models are quite formidable, and considerable work remains to be done before we have models and estimates in which we may place great confidence. Nonetheless, thanks to the combined experimental and modeling work of a number of scholars, tremendous progress has been made in the 1970s in analyzing the nature of jury decision-making and in drawing normative policy implications from the results of this analysis.[25]

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[25]To predict the impact of changes in jury size and decision rule, the strategy we recommend is to attempt a synthesis of data from well-designed experimental and quasiexperimental (before and after) designs with the results of probabilistic modeling. Each technique has its pitfalls and limitations. Together, they may enable us to form plausible conclusions about the basic nature of the social decision process in juries of various sorts, and thus about process and outcome characteristics of jury decision-making (cf. Zeisel & Diamond, 1974. See also Grofman, 1980b; & Grofman, 1980c).

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