A Conversation About *Collins**

William B. Fairley†
Frederick Mosteller‡

People who wish to apply probability, statistics, and mathematics to legal work find careful analyses of the facts in specific cases rewarding. *People v. Collins*[1] is a particularly good case for such study, because the prosecution used a probabilistic argument to try to establish an identification. Unfortunately, students tend to point out an initial difficulty in the prosecutor's argument and then dismiss the case. As the court recognized, however, the issues involved are deeper and deserve far more attention. Professor Hans Zeisel is famed for his ability to give clear explanations of very difficult statistical ideas. In his honor, we shall try to emulate him by discussing some of the issues raised by this case in a dialogue between a lawyer and a statistician. Neither of the participants presumes the other to have a specialist's knowledge of his field.[2]

The dialogue is intended to discuss three points. First, it considers the question of whether dependent or independent probabilities were the basis for the prosecutor's argument in *Collins* and offers an interpretation more favorable to the prosecution than that usually given. Next, it suggests that data could have been assembled to make a reasonable estimate of the order of magnitude of the probability. The prosecution, however, did not provide any such evidence, and the court considered the consequences of accepting the prosecution's unsupported numbers. The court, in an appendix to its opinion, developed a prob-

---

1 68 Cal. 2d 319, 438 P.2d 33, 66 Cal. Rptr. 497 (1968).

2 We call upon specialist knowledge in only one or two footnotes, and these notes may be passed over. For a discussion by a lawyer of *Collins* that presents an extensive exposition of elementary probability theory, see Cullison, *Identification by Probabilities and Trial by Arithmetic (A Lesson for Beginners in How to be Wrong with Greater Precision),* 6 HOUSTON L. REV. 471 (1969).

abilistic model intended to show that the identification was weak even if the prosecution's numbers were accepted. The court apparently concluded that if a random item sampled from a large population belongs to a rare type, then the probability of at least one more item of that type in the population is about 0.41. The third goal of this dialogue is to consider the validity of the model that gave rise to this number. The conclusion reached in *Collins* deserves to be reviewed with some care. More than one valid model, and more than one interpretation, is possible; our treatment is intended to provoke further discussion of these matters.

I. Prefatory Note on *People v. Collins*

Janet and Malcolm Collins were convicted in a jury trial in Los Angeles of second-degree robbery. Malcolm appealed his conviction to the Supreme Court of California, and the conviction was reversed. The court described the events of the robbery as follows:[3]

> On June 18, 1964, about 11:30 a.m. Mrs. Juanita Brooks, who had been shopping, was walking home along an alley in the San Pedro area of the City of Los Angeles. She was pulling behind her a wicker basket carryall containing groceries and had her purse on top of the packages. She was using a cane. As she stooped down to pick up an empty carton, she was suddenly pushed to the ground by a person whom she neither saw nor heard approach. She was stunned by the fall and felt some pain. She managed to look up and saw a young woman running from the scene. According to Mrs. Brooks the latter appeared to weigh about 145 pounds, was wearing "something dark," and had hair "between a dark blond and a light blond," but lighter than the color of defendant Janet Collins' hair as it appeared at trial. Immediately after the incident, Mrs. Brooks discovered that her purse, containing between $35 and $40, was missing.
> About the same time as the robbery, John Bass, who lived on the street at the end of the alley, was in front of his house watering his lawn. His attention was attracted by "a lot of crying and screaming" coming from the alley. As he looked in that direction, he saw a woman run out of the alley and enter a yellow automobile parked across the street from him. He was unable to give the make of the car. The car started off immediately and pulled wide around another parked vehicle so that in the narrow street it passed within six feet of Bass. The latter then saw that it was being driven by a male Negro, wearing a mustache and beard. At the trial Bass

---

3 68 Cal. 2d at 321, 438 P.2d at 34, 66 Cal. Rptr. at 498.

identified defendant as the driver of the yellow automobile. However, an attempt was made to impeach his identification by his admission that at the preliminary hearing he testified to an uncertain identification at the police lineup shortly after the attack on Mrs. Brooks, when defendant was beardless.

In his testimony Bass described the woman who ran from the alley as a Caucasian, slightly over five feet tall, of ordinary build, with her hair in a dark blond ponytail, and wearing dark clothing. He further testified that her ponytail was "just like" one which Janet had in a police photograph taken on June 22, 1964.

At the trial, following testimony by a college mathematics instructor, the prosecutor introduced a table in which he hypothesized the following probabilities of occurrence of the reported characteristics of the two people involved in the crime:[4]

Characteristic	Individual Probability
A. Partly yellow automobile	1/10
B. Man with mustache	1/4
C. Girl with ponytail	1/10
D. Girl with blond hair	1/3
E. Negro man with beard	1/10
F. Interracial couple in car	1/1000

The prosecutor multiplied these individual probabilities and arrived at a figure of 1/12,000,000, which represented the probability "that any couple possessed the distinctive characteristics of the defendants."[5] In his summation, the prosecutor repeated this analysis and emphasized the extreme unlikelihood—"somewhat like one in a billion"—that a couple other than the defendants had all these characteristics.

II. A CONVERSATION ABOUT *Collins*

Lawyer: The California Supreme Court made a lot out of the prosecutor's unproven assumption that each of the six characteristics was "statistically independent." Will you explain that to me?

Statistician: Statistical independence between X and Y means that it is neither more nor less likely that Y happens whether or not X happens. For example, in drawing a card from an ordinary pack of playing cards, let X mean the card is an ace and Y mean the card is black. The probability that the card drawn is black (rather than red) is 1/2, whether or not the card is an ace.

---

4 *Id.* at 325–26 n. 10, 438 P.2d at 37, 66 Cal. Rptr. at 501.

5 *Id.* at 325, 438 P.2d at 37, 66 Cal. Rptr. at 501.

L: Then the prosecutor's assumption was not merely unproven, it was almost certainly wrong. For example, it must be much more likely that a man has a mustache if he has a beard than if he does not. Beards and mustaches tend to run together. And, if you have a "girl with blond hair" and a "Negro man with beard," the chance that you have an "interracial couple" must be close to 1000 times greater than the estimate of 1/1000. Right?

S: Yes, everyone notices these dependencies.

L: I don't believe that the prosecutor could have blundered that badly.

S: The court seems to have thought that he did. The 1/12,000,000 figure was certainly consistent with treating each of the characteristics as statistically independent and, according to the product rule, multiplying the probabilities of each to get the probability of all together.

L: What is the product rule?

S: You use it yourself all the time. What are the odds of getting heads if you toss a coin?

L: Fifty-fifty.

S: Yes, that makes the probability one in two or one-half. And if you toss it again?

L: Same.

S: Right. What is your chance of getting heads both times?

L: One in four.

S: Right; one-half times one-half. That's the product rule. The prosecutor may have arrived at 1/12,000,000 by multiplying all of the individual probabilities of each characteristic occurring alone.

L: But if there is dependence that wouldn't be right.

S: Yes, but I will explain how the individual probabilities used in the case are also consistent with an interpretation that is more favorable for the prosecutor.

L: What is that?

S: He may have been employing the product rule for dependent events. If we work backward in the table from (F) to (A) and appropriately define the characteristics, this interpretation is at least plausible. For (F), at the time of the trial, 1 in 1000 might have been an accurate frequency for interracial couples who sometimes drive cars. For (E), among interracial couples who sometimes drive, perhaps 1 in 10 had a Negro man with a beard.

L: In 1964 beards were much rarer than in 1974.

S: For (D), among couples having both of these characteristics, one can argue that 1 in 3 has a woman with blond hair. We could go on,

interpreting each of the individual probabilities as a conditional probability, that is, given all of the preceding characteristics. If the individual probabilities were constructed in this manner, and if they were numerically correct, then their product would give the probability of the joint occurrence of the separate events or characteristics—those no longer regarded as independent. Of course I don't know if that's what the prosecutor had in mind, but it's a lot more plausible than the assumption of independent events.

L: But the resulting figure is the same either way.[6]

S: Yes.

L: Will you explain that?

S: Ordinarily we would have two different sets of probabilities for the characteristics, one representing the unconditional probabilities of events and the other representing the conditional probabilities for the characteristics in the order we choose for computation. If the probabilities in the table are the approximately correct conditional probabilities, then they are not likely to be the correct unconditional probabilities. For example, consider (E), "Negro man with beard." The population proportion of Negroes would be 10 or 12 percent, and the proportion of Negro males would be 5 or 6 percent; the proportion of Negro males with beards would be smaller still, say 2 percent. For (E) in 1964, the unconditional probability might therefore be about 1/50, rather than 1/10. If we change all of the probabilities to unconditional probabilities in this manner, then their product will not—except by a fluke—equal 1/12,000,000.

L: In this case, if you used unconditional probabilities as if there were independence, that would be a mistake, wouldn't it?

S: Yes; but if the separate probabilities given in the table are conditional probabilities, then the product rule for dependent probabilities would have been correctly used if we multiplied them together as we described.[7]

---

6 Charles Kingston has made an illustrative calculation of the probability of the joint occurrence of characteristics (A) through (F) that gives a figure close to 1/12,000,000. He made explicit assumptions about dependencies among the characteristics and, in addition, used a revised list of characteristics that removes the ambiguities and overlaps in the original list. Kingston, *Probability and Legal Proceedings*, 57 J. CRIM. L.C. & P.S. 93 (1966).

7 A simple example may clarify things. Suppose we have two young men and three old men; suppose also that one of the old men is a plumber and none of the other men are. The probability that a man drawn at random is a plumber is 1/5; the probability that a man drawn at random is old is 3/5. The assumption of independence between being older and being a plumber would give us the probability of selecting an older man who is a plumber as 3/5 times 1/5, or 3/25, which is clearly wrong. A correct attack would be to note that the probability of drawing an older man from this group is 3/5. Given that a man is old, the probability of that person also being a plumber is 1/3. We multiply 3/5

L: So the prosecutor may have been basically correct in getting an order of magnitude estimate for the frequency of couples with the characteristics of the robbers.

S: Possibly.

L: Still, even if the prosecutor intended to use the product rule for dependent events, he had not verified the individual probabilities he quoted.

S: But he could have taken some small steps in this direction. Suppose he had a small sample survey; this technique is sometimes used, though not always accepted by courts.[8] He could then have estimated the proportion of white girls with ponytails, the proportion of yellow cars, the proportion of black men with beards, and so on.

L: Since these numbers would have been just estimates, would the court have accepted them?

S: I don't know; that's your field, not mine.[9] But it would have at least had a chance to consider whether the method of gathering the data was adequate for the purpose. Remember that this analysis was an order of magnitude argument, and the court might have been sympathetic to a carefully made one. The court certainly suggested this attitude by developing its own mathematical model. Indeed, part of the court's complaint was that there was no effort by the prosecution to connect the numbers with the real world.

L: You mean he might just go out and count numbers of people of different types passing corners near the scene of the robbery at about 11:30 in the morning? Or ask the Registrar of Motor Vehicles to tell him what fraction of cars were yellow?

S: Yes, at a minimum. He might do better than that—but let's not get very far into the possible designs of his sample survey.

L: How could he handle the dependence problem?

S: By looking at pairs and triples of characteristics in his sample. For example, he might have counted 1,000 cars in the relevant neighborhood

---

times 1/3 to get the correct probability, 1/5, of drawing an old man who is a plumber. This last approach is an application of the product rule for dependent events.

More generally, if P(A) is the probability of event A occurring, and P(B|A) is the probability that event B occurs given that A occurs, then the probability of both A and B occurring is given by the product:

$$P(A \text{ and } B) = P(A) [P(B|A)].$$

8 *Cf.* Hans Zeisel, *Statistics as Legal Evidence,* 15 INTERNATIONAL ENCYCLOPEDIA OF THE SOCIAL SCIENCES 246 (1968); Zeisel & Diamond, *"Convincing Empirical Evidence" on the Six-Member Jury,* 41 U. CHI. L. REV. 281, 293 n. 52 (1974).

9 *See* Zeisel, *The Uniqueness of Survey Evidence,* 45 CORNELL L. Q. 322 (1960). *See also* Sprowls, *The Admissibility of Sample Data into a Court of Law: A Case History,* 4 U.C.L.A. L. REV. 222 (1957).

at the relevant time. He might have seen no cars with a couple like the one described, and he might have seen a few having as many as three of the required characteristics. Then he might be able to assess the rarity of the separate combinations of characteristics. Although it might be hard to determine a single collective probability, he would be able to define ranges of possible answers. The prosecution would then have a solidly based estimate of the rarity of the couple's charactertistics. There are special statistical tools for handling probabilities of several characteristics that are not independent.[10] It would be an uncertain estimate, for example, fixing the probability between 1/10,000 and 1/100,000.

L: Would he be estimating conditional probabilities or unconditional ones?

S: He would estimate the probability that all of the relevant characteristics are found in a randomly drawn couple. That probability is the figure that all of these calculations are intended to estimate.

L: I'm intrigued by the court's claim that "the prosecution's figures actually imply a likelihood of over 40 percent that the Collinses could be 'duplicated' by at least *one other couple who might equally have committed the San Pedro robbery.*"[11] What bothers me, I suppose, is the idea that a mathematical appendix could prove something about the likelihood of the existence of couples of a certain type. That's an empirical question. I'd have thought that a sample survey or a census would be the only way to find out how many couples sharing a given set of characteristics were in the area of the robbery.

S: It certainly is an empirical question, and we have discussed in principle how the data needed to answer the question might be gathered. The court, however, was trying to show what could be said without any data. They said, in effect, "Let's assume with the prosecution that the probability that a random couple would share the robbers' characteristics is 1 in 12,000,000."

L: And then the court imagines randomly selecting some number of couples from all of the couples who could have committed the crime, one of whom (the defendants) was observed by the police to have the listed characteristics.

S: Yes. Let's call this number N. If we independently select N couples, each with a probability of 1 in 12,000,000 of sharing the robbers' characteristics, we can then calculate the probabilities of selecting none

---

10 *Cf.* Y. BISHOP, S. FIENBERG, & R. HOLLAND, DISCRETE MULTIVARIATE ANALYSIS (MIT Press, in press).

11 68 Cal. 2d at 331, 438 P.2d at 40, 66 Cal. Rptr. at 504 (emphasis in original).

or one or more couples with these characteristics. If we put all those probabilities together, we get what's called the probability distribution of the number of such couples. Among the N couples.

L: How do you find these probabilities?

S: That calculation is made within probability theory, that is, these probabilities can be computed from a formula using the assumptions the court made. But we can carry out a simulation of the selection process that would illustrate these probabilities.

L: How?

S: We would randomly select N couples from the general population and record the number of couples selected that have the unusual characteristics. We would perform this selection process a number of times —perhaps a thousand—and the relative frequency of times we found no couples, one couple, two couples, and so on, would approximate the respective probabilities of finding, among N couples, no couples, one couple, two couples, and so on, with the unusual characteristics.

L: The court discusses conditional probabilities of different numbers of such couples. What are those?

S: The court says that the defendants are one couple with the characteristics of the robbers. According to the court, we should therefore be interested in probabilities that are conditional on that fact. That is, instead of asking for the chances of none or one or more, ask: if one, what are the chances of more than one? What is the probability of at least one more couple having the robbers' characteristics, given that there is one?[12]

L: I suppose that you could also simulate that probability.

S: We could go back to our earlier simulation and pick out all those selections of N couples having at least one couple with the required characteristics. We would then group these selections into those in which exactly one couple with the characteristics was selected and those in which more than one were selected. Of course, we ordinarily use a formula to make the calculation—as the court did.

L: So the court was saying that, in our case, if we collect all the selections of N in which at least one couple like the robbers was chosen, 41 percent of them will have more than one such couple. Is that right?

---

12 The issue stressed here is whether there is more than one couple. One could note that, even when there is more than one couple, each couple has a chance of being the couple of interest. The total probability that the defendants are the couple in question would then be a sum. The sum is composed of the probability that there was exactly one couple like the robbers plus part of the probability that there are exactly two, and so on. We shall not go into this aspect of the problem here. For a discussion of the probability of duplication and the probability of identity, see Kingston, *Applications of Probability Theory in Criminalistics*, 60 J. AM. STAT. ASS'N 70 (1965). *See also* Cullison, *supra* note 2.

S: Yes. You understand the court perfectly. But in fact the court was wrong. A crucial point at which the appendix is mistaken is that the conditional probability of there being more than one couple like the robbers, given that there was at least one, is 0.41 only if N is about 12,000,000.[13] And the court itself recognized that we don't know what number N really is.[14]

L: How did the court go wrong?

S: I don't know. To reach its conclusion the court had to believe that N was 12,000,000. And it says it didn't believe that.

L: Doesn't the 1 in 12,000,000 figure that the court took from the prosecutor imply a selection of at least 12,000,000 couples?

S: No. Suppose we flip a coin ten times. There are 1,024 possible outcomes; if heads and tails have equal chances of coming up on each toss, then each possible outcome has an equal chance, 1/1,024, of occurring. In this instance the probability comes from the product rule, which is applicable because each flip of the coin is an independent event. We might have only one set of 10 tosses yielding only one out-

---

13 The court formulated a model leading it to compute a binomial probability where the number of trials (couples) is N and the probability of a success (picking a robber-like couple) on any one trial is p. The court gives the well-known general formula for solving this problem, which we do not reproduce here. *See* 68 Cal. 2d at 334, 438 P.2d at 42, 66 Cal. Rptr. at 507. In the general formula p need not be 1/N, but the court used p as 1/12,000,000 to follow up the prosecutor's argument. The expected number of successes in N trials is Np. Because N is large and p is small, Poisson probabilities closely approximate the binomial probabilities, where Np is the mean of the approximating Poisson distribution. If we denote Np by m, the conditional probability sought is

$$\frac{\text{probability of more than one}}{\text{probability of one or more}}$$

$$= 1 - \frac{\text{probability of exactly one}}{\text{probability of one or more}}$$

$$= 1 - \frac{me^{-m}}{1-e^{-m}}$$

$$= 1 - \frac{m}{e^m - 1}.$$

The number e is the base of the natural logarithm and has an approximate value of 2.71828.

Here e^{-m} is the probability of zero couples sharing the characteristics of the robbers, $1-e^{-m}$ the probability of one or more such couples, and me^{-m} the probability of exactly one. When m is small the required conditional probability is approximated by

$$m/2.$$

For m=1, this approximation gives 0.5 instead of the more nearly exact value of 0.41. When p is taken as 1/N, then m=1 and we get the court's results. But p might not be 1/N and and thus m need not be 1; it could be much smaller or much larger.

14 "N, which represents the total number of all couples who might conceivably have been at the scene of the San Pedro robbery, is not determinable . . . ." *Id.* at 335, 438 P.2d at 43, 66 Cal. Rptr. at 507.

come, yet we have a probability for that outcome of 1 in 1,024. So there is no need to have anything like a thousand flips.

L: So there's no special case for N being 12,000,000 just because the probability of each selection is 1/12,000,000. Suppose we try a small N, perhaps because we believe the robbers must have come from a small area in San Pedro near the scene of the robbery. Try 250,000 instead of 12,000,000.

S: O.K. We can get the answer to this question from the general formula given by the court that shows how the conditional probability varies with N.[15] When N is 250,000, assuming that the probability of any couple having the robbers' characteristics is still 1/12,000,000, the probability of finding more than one couple if there is at least one is about 0.01.[16]

L: That's about one-fortieth of the court's figure.

S: Yes.

L: No wonder we have that quote from Disraeli about liars, damn liars, and statisticians.

S: Actually, the original saying referred to expert witnesses, not statisticians.[17]

Your common sense is basically right about this aspect of the problem. A couple could have such rare properties that it wouldn't be observed once in a month of Sundays. We all know this. Further, we know that the fact that there is one such couple, does not imply there are more. There may be, and the court's model is one way to think about it. But we should not get carried away with the details of the model or the implication of the court's example. The court's example is somewhat misleading. It suggests that when probabilities are small and we observe one rare object, there are quite likely two or more of them, in fact, 41 percent likely.

L: Earlier, I chose a number for N that made it likely that the defendants were the robbers. Couldn't the actual numbers have favored them even more than the court's example?

S: Certainly. If there are 250,000 couples and the probability that a given couple has the required characteristics is, for example, 1/25,000

---

15 *Id.* at 334, 438 P.2d at 42, 66 Cal. Rptr. at 507.

16 Using $m = Np = (250,000) \times (1/12,000,000) = 1/48 \sim 0.02$, we get $m/2 \sim 0.01$.

17 "There is probably no department of human inquiry in which the art of cooking statistics is unknown, and there are sceptics who have substituted 'statistics' for 'expert witnesses' in the well-known saying about classes of false statements. Miss Nightingale's scheme for Uniform Hospital Statistics seems to require for its realization a more diffused passion for statistics and a greater delicacy of statistical conscience than a voluntary and competitive system of hospitals is likely to create." SIR EDWARD COOK, 1 THE LIFE OF FLORENCE NIGHTINGALE 433-34 (1913).

instead of 1/12,000,000, then the odds are overwhelming[18] that there is at least one more couple with those characteristics.

L: So, if I understand you, the court's argument—that the prosecution's probability of 1/12,000,000 implied a probability of 0.41 for a second couple having the robbers' characteristics—is true only if N equals 12,000,000, an assumption that the court rejected because N was, in its words, "not determinable."

S: That sums it up accurately.

L: I'd like to clear up the meaning of these "selections" of N couples used by the court. I can understand the meaning of the probabilities we have discussed if I think of Los Angeles as a large goldfish bowl—which I am told it is—and imagine selecting N couples at random from the bowl and noting their characteristics. But how do we connect it all to *Collins?*

S: I think of it a little differently. I think of Los Angeles as generating couples who go out into the San Pedro area, different sets of couples each day, or even each hour. We could find out roughly how many couples there are in the area during a short time period around the robbery, and that figure could be regarded as the number of couples. Some days there would be no couples of a given unusual type, some days one, and so on. If we used the court's formula, we would estimate the probability of a couple having the robbers' characteristics, and then apply the N that is appropriate for the place and time of day.[19]

L: Wouldn't there be a tendency for a given region to have the same couples every day?

S: Yes, and for that reason we might want to use a somewhat more complicated model than that presented by the court, but let's save that for another time.

L: In addition to the unknown N, I don't know what to do with the 1 in 12,000,000 frequency figure, or even a 1 in 12,000 figure. In either case we are likely to find a substantial possibility of one or more other couples having the robbers' characteristics. In the first case there may be only one other couple, whereas in the second there may be a thousand. But the logical point of our discussion is that, without any other evidence, the chance that there was only one couple like the robbers is now something between 100 to 1 in favor and 2,200 to 1 against.

---

[18] Under this assumption, the odds are about 2,200 to 1. The simple approximation technique used above cannot be used here, because m, or Np, is not small. *See* notes 13 & 16 *supra.*

[19] The Collinses were identified as having been in San Pedro at the time of the robbery, 68 Cal. 2d at 322, 438 P.2d at 34, 66 Cal. Rptr. at 498, so the question remains: given one, what is the probability of more than one?

S: Yes, and that shows how important it is to get a fair estimate of the proportion of robber-like couples and the number of eligible couples. Before you heard this logical point, the unusual observed characteristics seemed telling, didn't they?

L: Yes, and that is what is puzzling me now. Reading all the facts, including the evidence in addition to that included in the probability model, I thought I saw a strong case against the defendants, but now I have doubts, and I can't justify that earlier view or intuition.

S: If we had time, I would discuss with you a way to think about the odds that takes into account the unusual characteristics and the other evidence in the case. I'd also like to discuss the implications of possible errors of observation by the eyewitnesses to the robbery.[20] There is also the fact that the particular characteristics in this case were selected, and omitted, in a post hoc way, and that might have made a difference.[21] Finally, we have suggested the need for somewhat more complicated models than those we have discussed.

L: Perhaps these models should be discussed in another conversation.

S: No doubt it will take more than one conversation. The *Collins* court, in its opinion and appendix, took a big step towards moving the ideas of probability into legal discussion in such cases. A first step into new territory is rarely the last.

---

20 These questions are taken up in Fairley, *Probabilistic Analysis of Identification Evidence,* 2 J. LEGAL STUDIES (1973). *See also* Finkelstein & Fairley, *A Bayesian Approach to Identification Evidence,* 83 HARV. L. REV. 489 (1970); Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process,* 84 HARV. L. REV. 1329 (1971); Finkelstein & Fairley, *A Comment on "Trial by Mathematics,"* 84 HARV. L. REV. 1801 (1971); Tribe, *A Further Critique of Mathematical Proof,* 84 HARV. L. REV. 1810 (1971).

21 Cullison remarks that "the prosecutor's descriptions seem to do a better job of describing the defendants than of describing what was fairly established about the robbers." Cullison, *supra* note 2, at 503.