

## THE LOGIC OF INFERENCE IN CRIMINAL JUSTICE STATISTICS\*

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An approach to teaching criminal justice statistics is advanced that focuses on broad similarities between all inferential tests. Tests of inference include all processes in which a hypothesis is generated and, ultimately, rejected or not. The process of a criminal trial, which is an inferential test, is employed as an extended analogy, through which specific statistical concepts are introduced. The advantages to criminal justice students of learning statistical concepts through a justice-specific framework are discussed.

The Special Section on Teaching Statistics and Research Methods that appeared in this journal (v.10[2]) identified a number of impediments to teaching criminal justice statistics and offered strategies and practical advice to improve instruction in such courses. A forum to address such concerns had been long overdue. As research and quantitative methods courses have increasingly become a central focus in criminal justice curricula (DiCristina 1997), resources for improving instruction in these courses become a valuable asset. The intent of this paper is to present an additional heuristic strategy that may improve the quality of instruction in quantitative methods courses. Specifically, an approach to teaching the logic of inferential tests, geared toward justice students, is advanced.<sup>1</sup>

Justice statistics instructors face a number of challenges. Byers (1999:325) identifies what appears to be a consensus view among statistics students—"students in general. . .tend to view research methods and statistics as boring." Failing to regard statistics as fascinating is baffling to those who enjoy the subject matter, however, when one considers the unquestioned conventions of *teaching* statistics (e.g., presenting proofs and demonstrating probabilities with the standard 'coin toss' example), it is equally puzzling that students do not revolt.

There are problems with statistics courses beyond boredom and unimaginative teaching approaches. Chermak and Weiss (1999) suggest

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<sup>1</sup>Inference is but one function of statistics. The author does not contest Zeller's (1999) contention that principles underlying descriptive and inferential statistics differ. In this, a device that may be limited to teaching the logic of inference is advanced.

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that justice statistics students have high levels of anxiety. Byers (1999) states that such students are 'terrified' when taking quantitative courses. Obstacles such as anxiety can be negotiated by formulating an approach to teaching statistics that does not rely on technical and less-than-instructive subject matter (e.g., proofs). The crucial subject matter of statistics is not difficult to understand. Traditional teaching approaches, however, have made it seem so.

The approach to teaching the logic of inference introduced in this paper addresses the problems of boredom and anxiety by employing justice-related concepts that are of inherent interest to, and are readily understood by, justice students. These familiar concepts are used to illustrate less familiar, often confusing, statistical concepts. Such an approach is advantageous for justice students as it provides a framework for understanding the underlying logic of all inferential tests, as will be demonstrated, without inducing panic or slumber.

The paper advances in a straightforward manner:

- 1) A heuristic device for teaching justice students the logic of inference is presented and
- 2) The pedagogical advantages of this device are considered.

### CRIMINAL TRIALS AND THE LOGIC OF INFERENCE

Statistics courses, especially those taught in mathematics departments, introduce statistical tests only after a number of proofs are performed to justify the assumptions of such tests, the values of probability distributions are computed and the formulae for test statistics are presented. An alternative approach, which may be better suited to justice students, allows instructors to present statistical concepts and tests within a framework that is not primarily mathematical. Rather, statistical concepts and tests may be introduced using an analogy that justice students will find familiar, less intimidating and intuitively appealing.

The approach proposed herein allows students to discover for themselves that they already understand the basic logic underlying statistical tests—the logic of inference. Tests of inference include all processes in which a hypothesis is generated and, ultimately, is rejected or not. As such, two types of inferential tests are criminal trials and statistical tests. In criminal trials, a hypothesis that the defendant is innocent is either rejected by way of a guilty verdict or not.<sup>2</sup> In statistical tests, null hypotheses about proposed relationships between an independent and dependent variable observed in a sample are either rejected or not.

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<sup>2</sup>The idea of a criminal trial as a metaphor for inferential tests is not as original as I had naively supposed. I was directed to Bachman and Paternoster's (1997) brief use of the analogy in their statistics text. They attribute the idea to Professor Daniel A. Powers. In this, the value of this work is not in advancing a novel idea, but in demonstrating how this idea may be applied to advantage justice students.

Criminal justice students will tend to be familiar with criminal trials and less familiar with the abstract language and notation of statistics. Allowing students to make connections between familiar features of criminal trials and relatively novel analogs related to statistical tests serves as a powerful heuristic device. Zeller (1999:352) describes how this transitive approach may be advantageous in teaching *descriptive* statistics to criminal justice students— “In teaching students something that is difficult to understand intuitively, the best strategy is to find something about which they trust their intuitions and to show the similarity of these two things.” The current paper seeks to do the same for inferential statistics.

The proposed approach exploits students’ intuitive understanding of the criminal trial process, using the familiar concepts associated with criminal trials as analogs to less intuitive concepts in statistical tests. The use of analogies has served as a beneficial pedagogical tool both for criminal justice statistics and for general topic areas of criminal justice. In regard to the use of analogies in criminal justice statistics, a particularly clever analogy to explicate the conceptual differences between reliability and validity is presented in Maxfield and Babbie (1994).<sup>3</sup> Zeller (1999:352) also proposes using analogies to help criminal justice students conceptualize measures of central tendency, likening the mean to a fulcrum (or the middle of a see-saw).

In regard to the use of analogies for general criminal justice topics, the notion of *parens patriae* has long served as an aid in conceptualizing the differing approaches of the adult and juvenile justice systems. Likening the role of the State in the juvenile system to that of a parent serves to explain the relatively nurturing and forgiving approach of the juvenile system. Analogies have also been closely associated with major theoretical movements in the study of criminal behavior. Analogies summarize the differing conceptualizations of offenders within the most deterministic theories (in which individuals are viewed as machines whose actions are largely programmed by their traits) as well as those theories that stress free will (in which individuals are informed, rational calculators).

Analogies may serve as highly effective pedagogical tools only to the extent that they clarify rather than distort students’ understanding of concepts. Avoiding distortions can be difficult as analogies seek to make a comparison between two separate entities that may share certain features but may also differ in key ways (see Hesse [1966] for an explication of this problem in the physical sciences). The main problem with analogies is that they are not similes. As such, those who are literally-minded may expect a

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<sup>3</sup>Maxfield and Babbie (1994:111) use the grouping of shots on a target as an analogy for the concepts of reliability and validity. Reliable and valid measures are presented as a tight grouping of shots in the bull’s-eye portion of the target. Valid but not reliable measures, due to random error, are presented as dispersed about the target. Reliable but not valid measures, due to systematic error are presented as a tight grouping of shots outside of the bull’s-eye.

parallel for each and every feature of analogous entities. Owing to this potential problem, the use of analogies should be aimed only at discerning broad similarities.

With caveats taken into consideration, a number of broad commonalities between two differing forms of inferential tests—criminal trials and statistical tests—can be proposed. In terms of practical application, students may be asked what the basic objective of a criminal trial is and how, procedurally, trials attain this end. A template emerges in which a defendant is presented to the court, evidence is presented and weighed by the arbiters (most imagine the arbiters to be jurors), and a verdict is reached. This formulaic process, with which students are comfortable and familiar, parallels the process of hypothesis testing (seen in Table 1). When the actions in a criminal trial are distilled to their basic essence as a number of logical steps, students may be convinced that they already understand the basic logic of inference—the same basic logic behind statistical tests.<sup>4</sup>

**Table 1. Shared Steps in Criminal Trials and Statistical Tests**

Steps in the logic of inference	Analogous steps in criminal trials	Analogous steps in inferential tests
1. A series of assumptions is made.	Null hypothesis of presumed innocence is stated.	Null hypothesis is stated as a hypothesis of no difference. Model and level of measurement assumptions are stated.
2. Criteria for rejecting assumptions are determined.	Verdicts will only be accepted if they are unanimous (save for verdicts in jurisdictions that depart from this decision rule in criminal trials).	A sampling distribution that assigns a probability to the occurrence of all possible test statistic values is determined. A critical region within the sampling distribution is selected.
3. A value is generated that relates to a theoretically relevant assumption in Step 1.	A verdict is generated through the deliberation of 12 jurors.	A test statistic is computed from a sample of independent cases.
4. A decision is made regarding the theoretically relevant assumption in Step 1.	The unanimous verdict is pronounced. A guilty verdict is a rejection of the null hypothesis of presumed innocence.	If the test statistic falls within a predetermined critical region of a sampling distribution, the null hypothesis is rejected.

<sup>4</sup>The model that I present in Table 1 is largely predicated upon Blalock's (1960) steps of hypothesis testing. Similar models are presented in recent texts such as Healey (1999). Healey's model differs in a slight manner from the model proposed herein. In Healey, model assumptions and hypotheses are presented in separate steps. Blalock and the present model, by contrast, present model assumptions and hypotheses in the same step in an attempt to

*Step 1. A series of assumptions is made.*

The assumptions that are made in inferential tests are rarely explicated with examples that are relevant and familiar to justice students. Though the difficulties of using such examples have been noted previously (Steinhorst and Keeler 1995 cited in Chermak and Weiss 1999), the assumptions employed in criminal trials are certainly familiar to justice students.<sup>5</sup>

*Null hypotheses.* Trials are held to resolve legal questions. In civil trials, questions of liability are resolved; in criminal trials, questions of guilt. In criminal trials, the burden of proof is upon the prosecutor. An assumption or, a *hypothesis* is made at the outset of a trial that the defendant is to be presumed innocent. A presumption of the defendant's innocence must be overcome by the power of the State's case for the defendant to be found guilty. The unresolved question in a criminal trial is not framed as "Is the hypothesis that the defendant is guilty, in fact, true?" but rather "Given that it is presumed that the defendant is innocent, has evidence been presented that is powerful enough to reject this initial presumption?"

Students can rehearse framing hypotheses as negatively stated questions, using the presumption of innocence as a tool for doing so. The negatively stated question (or presumption) of innocence in a trial parallels the construction of the null hypothesis in a statistical test. Suppose we want to test a hypothesis that there is no difference between green and red candy canes in regard to their sugar content. How can a hypothesis of 'no difference' be stated? Students work from a slightly reworded construction of the presumption of innocence in criminal trials—"the defendant standing before the court is no different from an innocent person"—to a parallel construction related to new samples—"The sugar content of green candy canes is no different from the sugar content of red candy canes."

*Step 2. Criteria for rejecting assumptions are determined.*

In criminal trials, there is an understandable concern about making errors or an incorrect decision about an uncertain hypothesis. With little prompting, students can catalog countless instances of perceived miscarriages of justice as they relate to criminal trials. There is no shortage of the forms of error that students may claim abound in criminal trials. There is the major error of verdicts that are perceived of as incorrect or unjust. Additionally, procedural errors, factual errors and other sources of error that jeopardize the administration of justice may be cited. These latter

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emphasize that the hypothesis is a form of assumption—one that will either hold up or fail under empirical testing.

<sup>5</sup>In regard to the organization of materials presented, the model assumptions related to level of measurement, unit of analysis, etc. should be dealt with in earlier lectures such as those on descriptive statistics (see Zeller 1999). As such, the discussion of assumptions will focus on hypotheses.

forms of error are of some concern to justice students, but the former errors (incorrect verdicts) more readily serve as an analogy to statistical error. *Statistical error* refers to making an erroneous decision about whether the null hypothesis should be rejected. A Type I error, in regard to a presumption that a defendant is innocent, is for a jury to reject this presumption (by entering a guilty verdict) when, in fact, the defendant is innocent. A Type II error is the converse— a jury fails to reject the presumption of innocence (by entering a not guilty plea) when, in fact, the defendant is guilty.<sup>6</sup>

Table 2 presents the decisions that can be made in regard to a (null) hypothesis that is, in nature, either true or false. Errors in criminal trials that are analogous to statistical errors are presented.

**Table 2. Types of Statistical Error and Their Analogs in Criminal Trials**

Null hypothesis—“the defendant standing before the court is no different from an innocent person”

	Reject the Null Hypothesis ('Guilty' Verdict)	Fail to Reject the Null Hypothesis ('Not Guilty' Verdict)	Neither Reject nor Fail to Reject the Null Hypothesis (No Verdict Returned)
The Null Hypothesis is True. (The Defendant is Innocent)	Type I Error (An Innocent Defendant is Found Guilty)	No Error (An Innocent Defendant is Found Not Guilty)	Unspecified Error (An Innocent Defendant is Not Found Guilty or Not Guilty)
The Null Hypothesis is False. (The Defendant is Guilty)	No Error (A Guilty Defendant is Found Guilty)	Type II Error (A Guilty Defendant is Found Not Guilty)	Unspecified Error (A Guilty Defendant is Not Found Guilty or Not Guilty)

It is interesting to note that erroneous outcomes in the differing cells of Table 2, though all representative of “error,” have profoundly divergent philosophical implications. In the social sciences, there is no strong preference for errors. Rejecting a null hypothesis that is in fact true (Type I error) is problematic in that erroneous findings may guide future decisions or enter, undeservingly, into the discipline’s literature. Type II error is

<sup>6</sup>An interesting difference between criminal trials and statistical tests arises out of the relative frequency to which no resolution may be reached in criminal trials. The conditions under which statistical tests may fail to be resolved are rare. Suppose we establish a critical region of  $p < .05$  for rejecting a null hypothesis and our test value is equal to .05 exactly. In such an instance, we are deadlocked. Fortunately, this is an uncommon occurrence and it may be dealt with in any number of creative ways, quite unlike the occurrence of hung juries. A hung jury represents some form of error, as the defendant is either guilty or not (and is not pronounced as such), but it is uncertain what type of error this would be.

problematic in that potentially influential findings will fail to be disseminated, if they are not recognized due to error. Neither form of error is preferable; both lead to mistaken conclusions and mistakes of any nature are problematic in the social sciences.

Criminal trials differ from statistical tests in regard to a preference for error. The notion of finding an innocent defendant guilty, traditionally, outweighs the society's concern over letting guilty defendants go free. Few are concerned about juries offering no verdict, which leads to defendants going free, but remaining subject to a subsequent trial. This form of unspecified error is inefficient and could be of greater concern to justice scholars and taxpayers.

Given the possibility that verdicts may be in error, in a statistical sense, what mechanism is employed to assess our confidence that the null hypothesis is not rejected erroneously? Surprisingly, verdicts are not assessed of their veracity or the probability that they are in error. Once jurors arrive at a verdict, it simply stands.

Perhaps there are reasons to believe that verdicts are obtained in such a manner as to minimize error. After all, criminal juries are asked to deliberate with each other until they have arrived at a unanimous verdict (or are hopelessly deadlocked). Perhaps the high decision costs of arriving at a unanimous verdict serves as some bulwark against error. Suppose only 7 of the 12 jurors initially desired to convict the defendant. If they manage to convince the remaining 5 jurors to change their votes, then the resulting verdict is less likely to be in error. Of course, such reasoning is foolish. Unanimous decisions do not reduce error. They simply make verdicts that may or may not be correct more costly to obtain.

Scholars and students may bemoan the error-fraught (in terms of statistics) manner in which juries reach verdicts in criminal trials. Few, however, can propose efficient methods for reducing such error. The interest of students in resolving such sources of error lends itself to an introduction to the *sampling distribution*—an entity that is traditionally difficult to conceptualize for students. The ability to present sampling distributions as instrumental to a possible solution to jury error, a topic for which justice students have an inherent interest, poses a definite advantage to criminal justice statistics instructors.

The introduction to the sampling distribution proceeds in the following way. The singular, deliberative body of the jury is converted into a sample of 12 individual jurors. Let us suppose that the unanimity rule was not the prevalent manner of arriving at a verdict and, thus, making a decision about a null hypothesis. Suppose instead that a jury of some number, 12 being as good as any, is selected. Each juror would be allowed to vote for acquittal or conviction after the completion of the State's and defense counsel's presentations. These 12 observations could then be considered to determine whether the State has presented a legal case compelling enough



to reject the null hypothesis of the defendant's innocence. For instance, if a single juror votes for conviction, there is a high probability that the State failed to make a compelling case and, by extension, the null hypothesis that presumes innocence is likely to stand. This is not to say a verdict of "not guilty" is pronounced as the defendant is presumed to be innocent at the outset. Rather, the number of juror votes for conviction was not large enough to reject the presumption of innocence. The result is the same as a "not guilty" verdict; the defendant is not convicted.

How many juror votes to convict would it take for us to be convinced that the null hypothesis that the defendant is innocent is not reasonable? Should a simple majority of 7 out of 12 voters be sufficient to reject the null hypothesis? It is likely that such a simple majority rule would lead to an unconscionably high number of false convictions. Since a sample is now being considered, the probabilities of Type I errors (or false convictions) can actually be computed. Suppose that each juror, before they are impaneled, has no personal stake in the case at hand. Some may be slightly inclined to convict, others slightly inclined to acquit, but on the whole, your average juror has no inherent inclination to acquit or convict. In other words, each juror has a probability of voting to convict 50% of the time independent of observing the State's case against a defendant.<sup>7</sup>

Given a jury of individuals who are neither inclined to convict or acquit, what is the likelihood of 10 out of 12 jurors voting to convict the defendant independent of the effect of the prosecution's case against the defendant?

The likelihood that 10 of 12 jurors would, as a matter of mere chance, vote to convict is .01611. However, if we accept a majority vote of 10 out of 12 to convict, it stands to reason that we would also accept the majority votes of 11 and 12 jurors voting to convict. Therefore, the cumulative probability of majority votes of 10, 11 and 12 to convict is .0192. In other words, out of 100 trials, about two trials may result in erroneous convictions, as a matter of pure chance, should such a voting rule be accepted.

Knowing the probability of such an outcome occurring by chance, should the votes of as few as 10 jurors be regarded as enough to convict? This question is difficult to divorce from its normative implications. Should we feel comfortable knowing that, statistically, 1 out of every 50 convictions occurred as a matter of chance? Suppose we are not comfortable with this number of erroneous convictions and will only reject the null hypothesis if at least 11 jurors vote independently to convict. The cumulative probability of such an outcome is much lower— with chance convictions occurring .31% of the time, or 1 out of every 322 trials.

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<sup>7</sup>This assumption is made so that the binomial distribution may be applied to the problem at hand. The rationale for such an assumption is a desire to make a heuristic point rather than a policy statement. For policy-oriented applications of this exact assumption in jury models, see Feddersen and Pesendorfer 1998.

**Table 3. Binomial Distribution for Jurors Voting to Convict**

Number of jurors voting to convict	Probability	Cumulative Probability
12	0.000244141	0.000244141
11	0.002929688	0.003173828
10	0.016113281	0.019287109
9	0.053710938	0.072998047
8	0.120849609	0.193847656
7	0.193359375	0.387207031
6	0.225585938	0.612792969
5	0.193359375	0.806152344
4	0.120849609	0.927001953
3	0.053710938	0.980712891
2	0.016113281	0.996826172
1	0.002929688	0.999755859
0	0.000244141	1

The main point is that a probability distribution can be determined that refers to the probability of all possible outcomes of a trial in which a sample of 12 jurors vote and do not have to reach a full consensus. When such a distribution is known, decisions about the degree to which we are comfortable making statistical errors of certain types may be made. For instance, in the above example, the probability of making a Type I error (rejecting the null hypothesis that the defendant is innocent when it is in fact true) is initially set at .0192 in accepting 10 or more votes as suitable to reject the null hypothesis. Subsequently, the number of votes necessary to convict is increased to at least 11, at which point, the likelihood of Type I error decreases to .0031 (or a Type I error occurs .31% of the time).

*Step 3. A value is generated that relates to a theoretically relevant assumption in Step 1.*

In jury trials, under the current unanimity rule with deliberating jurors, the value referred to in Step 3 would be the verdict that a jury produces. However, if criminal trials were conducted in a manner that more closely resembled statistical tests, the number of juror votes for conviction would serve as this value. The number of juror votes for conviction is the *test statistic*, and it relates directly to the null hypothesis (the “theoretically-relevant assumption in Step 1”). In statistical tests, this value is compared with known sampling distribution values. This value may or may not be within a predetermined critical region (such as our initial region of 10,11 or 12 juror votes to convict). Given that a predetermined number of jurors (rather than a probability level associated with a test statistic) establishes the threshold for conviction, this arrangement precludes the possibility of hung juries.

*Step 4. A decision is made regarding the theoretically relevant assumption in Step 1.*

This statement refers to the ultimate judgment of a decision-making process. In a criminal trial, under the traditional conditions, this step is equated with the pronouncement of a verdict. In this sense, a decision is made regarding the null hypothesis about the defendant's innocence (from Step 1) based on the verdict (Step 3) that has been obtained in a manner determined in Step 2 that reflects an effort to avoid errors or certain types of error. In statistical tests, similar decisions are made, but unlike a criminal trial with unanimous, deliberating jurors, a critical region within a sampling distribution is selected in advance of computing the test statistic to determine which values, should they be obtained, lead to a rejection of the null hypothesis.

### **ADVANTAGES OF USING JUSTICE-RELATED ANALOGIES TO TEACH STATISTICS**

As has been stressed earlier, all inferential tests employ a similar logic, though the particular features of tests may vary. In spite of such variation, a simple and broad framework is presented in which subsequent inferential tests, in the form of other statistical applications (such as analysis of variance or t-tests), can be readily assimilated.

There are advantages over traditional statistical pedagogy in introducing statistical concepts with a justice-related analogy. The first is the ability of such an approach to combat the boredom that seems to be inherent in statistics courses. This is done through the strategic use of justice-related concepts about which justice students are knowledgeable and interested. Another advantage is that such an approach bolsters students' confidence as they discover that they already understand the logic of inference—as they come to the class familiar with the logic behind the steps in a criminal trial.

Chermak and Weiss (1999) state that teachers find it difficult to teach in a manner that consistently utilizes justice-related examples to demonstrate concepts. One reason for this may be the weight of tradition. The criminal justice discipline does not have the long quantitative tradition that political science, psychology, economics or many other social sciences enjoy. For this reason, most instructors have learned statistics from monolithic texts like Blalock's (1960, reprinted in 1972 & 1979) *Social Statistics*. Blalock is masterful at explicating concepts, but his reliance on generic social science examples simply fails to interest students who have chosen to study the specific area of criminal justice. Providing justice-related examples, and choosing a text that does the same, should keep students relatively attentive while grounding their understanding of statistics within their chosen field.

A final advantage is the ability of such an approach to reduce the course's reliance upon proofs and other intimidating quantitative exercises. The ability to not rely so heavily on proofs and mathematical tautologies is crucial. Chermak and Weiss (1999) state that one of the largest obstacles to teaching justice statistics and a major source of anxiety is the fear of numbers. Proofs and the discipline of pen and paper computation are important, but they should not be the main focus of justice statistics courses. Why not? The fear of numbers may be particularly salient for students who study justice, a field in which approaches other than heavily quantitative ones may be pursued (DiCristina 1997). Unlike fields such as engineering or economics where the rationale for a quantitative emphasis is self-evident (Hansen 1991), facility with numbers may not be assumed for justice students. There are few reasons why a framework that employs a narrative logic based on problems within criminal justice may not be employed to reduce the intimidating mathematical formalism of statistics and to engage criminal justice students in statistical topics that are often regarded as dry, abstract or plain difficult.

### CONCLUSION

Ultimately, the success of a pedagogical approach is determined with regard to the ends it achieves. What are the ends or goals of justice statistics courses? McKean (1999: 327) states a number of possible goals for criminal justice statistics courses:

interpreting and using criminological data, reading and understanding research reports, adopting a scientific orientation, and applying the basic logic of causal reasoning.

The approach described above does not abandon any of these goals by attempting to attain them within a justice relevant framework. Finally, the approach proposed herein is uncommon in that it makes a realistic assessment of the difficulties involved in establishing a suitably modern quantitative orientation. The number of statistical applications appearing in justice and other social science journals is large and could not be taught in the average justice curriculum (Vijverberg 1997). It is also naive to imagine that what is taught traditionally (e.g., when to use the *z*- rather than the *t*-test; computing Fischer's exact values) can begin to equip the justice student to understand quantitative journal articles. Granting this, an approach that provides a broad template within which students recognize the component parts (or logical steps) of inference, allows for students to more readily assimilate new inferential tests or applications as they are introduced. These new applications become variations on a theme; the theme being the common steps in all inferential tests.

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