Approaches Toward Data Analysis

Traditional, Test-Based Inference

The traditional form of statistical inference was developed in the early part of the 20th century to address then needs of agricultural- and laboratory-based experiments. It starts by specifying a single hypothesis (e.g., does treatment A result in a better crop yield than treatment B?). Data are then collected, an underlying distribution of the sampling distribution is assumed, and data were submitted to testing. Conclusions are categorically "yes" or "no": either there is or isn't a significant difference in treatments. Often, the analysis begats a new hypothesis, and the process is begun anew, from scratch (Fig 1).

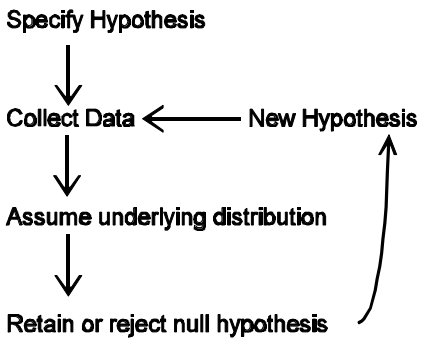

Figure 1. Classical, test-based method.

This test-based approach of inference, however, does it serve observational research questions equally well. For one, it is not meant to uncover previously unrecognized patterns or findings. Secondly, it ignores the potential for systematic errors in measurement and sampling, which are common with non-experimental data. Third, and perhaps most importantly, it fails to quantify observed differences, concluding only black-and-white differences, where they exist. Thus, the traditional test-based method of inference is not equally appropriate to all quantification purposes.

John Tukey Suggests How Knowledge and Belief are Bought

The philosophy, development, and promotion of newer methods of statistical inference owe much to the work and words of statistician-philosopher John Tukey. Tukey's work reminds us that both exploratory and confirmatory methods of analysis are often needed. He also reminds us that knowledge and belief have a price. When he asks, With what coin do we buy knowledge and belief? he identifies three kinds of payments. These are:

1. The care and insight with which data are collected and in which the study is planned and performed.
2 The effort involved in collecting enough data.
3. The formal error-rate that we are willing to accept as a basis for our conclusions.

Statistically, too often we focus on coin 3 to the exclusion of coins 1 and 2.

Tukey also reminds us to make careful descriptions our first step. Many of the newer analytic approaches, therefore, rely of numerical and graphical exploratory techniques as a prominent component of analysis. Confirmatory analyses, resembling classical hypothesis tests still pursued, but only after careful descriptions. Data may also be reused as additional patterns are uncovered. These newer confirmatory methods often rely on nonparametric, making fewer assumptions about underlying distributions. Data are reused to test more than a single hypothesis, which seems more practical, given the costs of high quality data and the availability of computer software that makes computationally intense analyses less

burdensome. If an analysis begets a new hypothesis, the data can then be reused, instead of collecting the data from scratch (Fig 2).

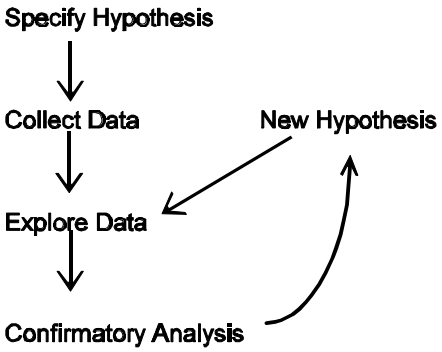

Figure 2. Modern, exploratory-based method.

Components of Analysis

The above discussion suggests that modern data analysis requires more than hypothesis testing. Specifically, it requires a consideration of the care in which data were collected, with exploratory quantification, using multiple descriptive forms (e.g., descriptive statistics, plots, and frequency tables). Estimation needs to be brought to the fore, considering both the direction and precision of estimates. Tests are still relevant, but only insofar as they shed light on qualitatively conclusions. Finally, there is the role of rhetoric, because the telling of a compelling and interesting story is an important part of belief. In summary, we must consider the following 5 points for each analysis performed:

(1) The research question and care used in collecting data.
(2) Exploratory techniques that include use of summary statistics, tables, and graphs.
(3) Estimates which quantify the direction and precision of the estimate (point and interval estimation).
(4) Confirmatory tests for significance, and the power of such analyses.
(5) Narrative summaries and principled argument based on documenting the sources and characteristics of the data and insistenty enforcing appropriate comparisons that demonstrate mechanisms of cause and effect.

It is also necessary to have a commitment to finding, telling, and showing the truth.

References

Tukey, J. W. (1969.) Analyzing data: Sanctification or detective work? *American Psychologist*, 24, 83 - 91.

Tukey, J. W. (1991). The philosophy of multiple comparisons. *Statistical Science*, 6, 100 - 116.