

## Sources of “Hidden” Uncertainty

- Systematic error
- Overconfidence
- Using means but neglecting scatter
- Extrapolating

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## Examples of Systematic Error

- Measurement procedure (e.g., speed of light, a scale that consistently underweighs)
- Using surrogate measures (e.g., measuring the amount of substance entering a process by measuring the amount in the ash, when some of the substance may be volatilized)
- Sampling procedure (e.g., sampling bank customers in the bank during a certain period to determine the average wait time in line.)

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## Systematic Error as a Result of Design of a Study

- “A well-designed empirical study reaches conclusions that tend to replicate *when correct* and are less likely to replicate *when incorrect*, whereas in a poorly designed study the conclusions tend to replicate even *when incorrect*” (Paul R. Rosenbaum, *American Statistician*, August 2001)
- Solution: Vary the assignment mechanism and the “treatment envelope”

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## Overconfidence as a Source of Hidden Uncertainty

- Disconfirming evidence may not be available.
- Seeking disconfirming evidence is difficult.
- Human tendency to discount available disconfirming evidence.
- Accepted beliefs are difficult to dislodge. (“Science requires evidence” - works both ways)

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## Examples of Using Means, Forgetting Scatter

- The Humble equation is widely used for calculating water saturation for sandstone in estimating oil reserves. It is based on a sample of size 30.
- Contour maps are often used without discussion of their precision.
- Using confidence intervals for prediction in regression. (Variability and uncertainty!)

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## Lessons to Learn

- Subjectivity (e.g., judgment) is often involved with what may appear to be objective.
- Subjectivity introduces uncertainty.
- Actively look for and be open to sources of uncertainty.
- “It is not the use of subjective judgment that is a mistake. That is generally unavoidable. The mistake is to ignore it, and hence overlook the introduction of major additional sources of uncertainty” (Morgan and Henrion, p. 59)

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## Examples of Extrapolation Problems

- A line can be a good approximation to a curve over a short range, but ...
- Why should an exposure model for chronic doses apply to acute doses?
- The Mobile5a emission factor model was developed by EPA to predict area-wide average emission factors, but is routinely misapplied to estimate emissions for individual highway segments.
- Hidden extrapolation: using combinations of input values not tested.

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## Methods for Dealing with Uncertainty in Models

- Use simple models such as triangular to incorporate rough estimates of uncertainty.
- Bayesian analysis
- Monte Carlo analysis (Use distributions rather than point estimates.)
- Point out uncertainty explicitly.

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