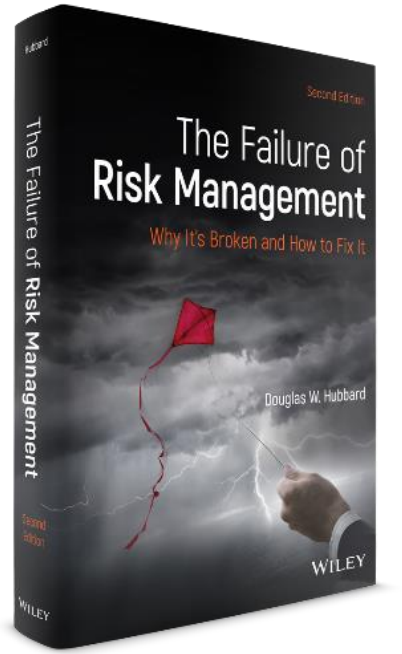
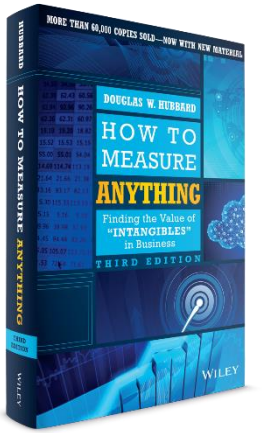
The Failure of Risk Management

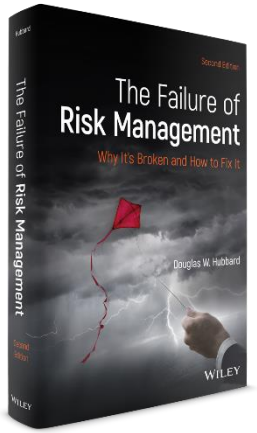


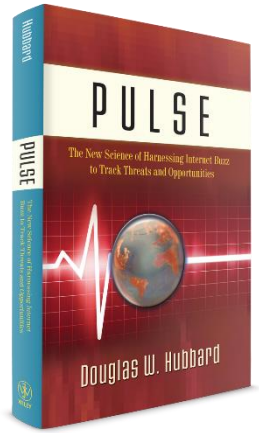
Hubbard Decision Research
2 South 410 Canterbury Ct
Glen Ellyn, Illinois 60137
www.hubbardresearch.com

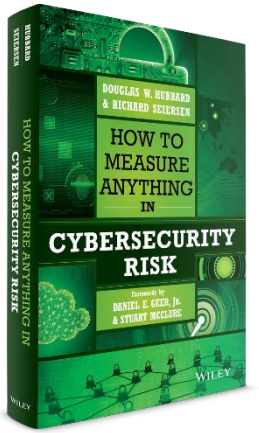
Introduction

My Books









Applied Information Economics (AIE)

Information Technology

- Prioritizing IT portfolios
- Risk of software development
- Value of better information
- Value of better security
- Risk of obsolescence and optimal technology upgrades
- Value of network infrastructure
- Performance metrics for the business value of applications

Business Investments

- Prioritizing R&D in aerospace, biotech, pharma, medical devices and more
- Publishing
- Real estate
- Movie/film project selection

Engineering

- Power and road infrastructure upgrades
- Mining Risks

Government & Non-Profit

- Environmental policy
- Sustainable agriculture
- Procurement methods
- Grants management
- Public schools

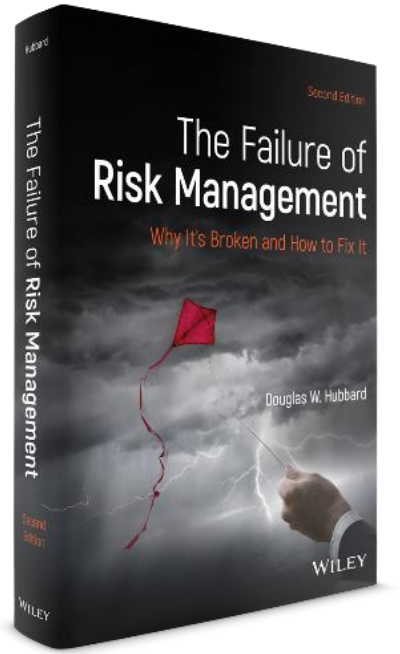
Military

- Forecasting battlefield fuel consumption
- Effectiveness of combat training to reduce roadside bomb/IED casualties
- Methods for testing equipment

Introduction

Topics for Today

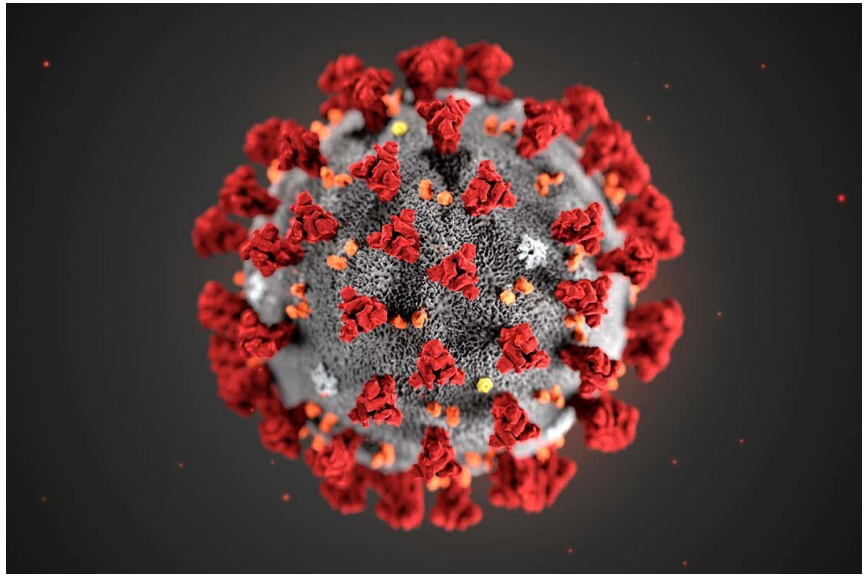
- The Meta-Decision
- Getting Started
- Obstacles
- Simple Math



Introduction

A Few Events from the Last 10 Years

- Fukushima Daiichi nuclear disaster (2011)
- Deepwater Horizon offshore oil spill (2010)
- Flint Michigan water system (2012 to present)
- Samsung Galaxy Note 7 (2016)
- Multiple large data breaches (Equifax, Anthem, Target)
- Amtrak derailments/collisions (2018)
- California utility PG&E wildfires (2018)
- ***COVID (2020)***



Introduction

The Biggest Risk

Question: What is your single biggest risk?

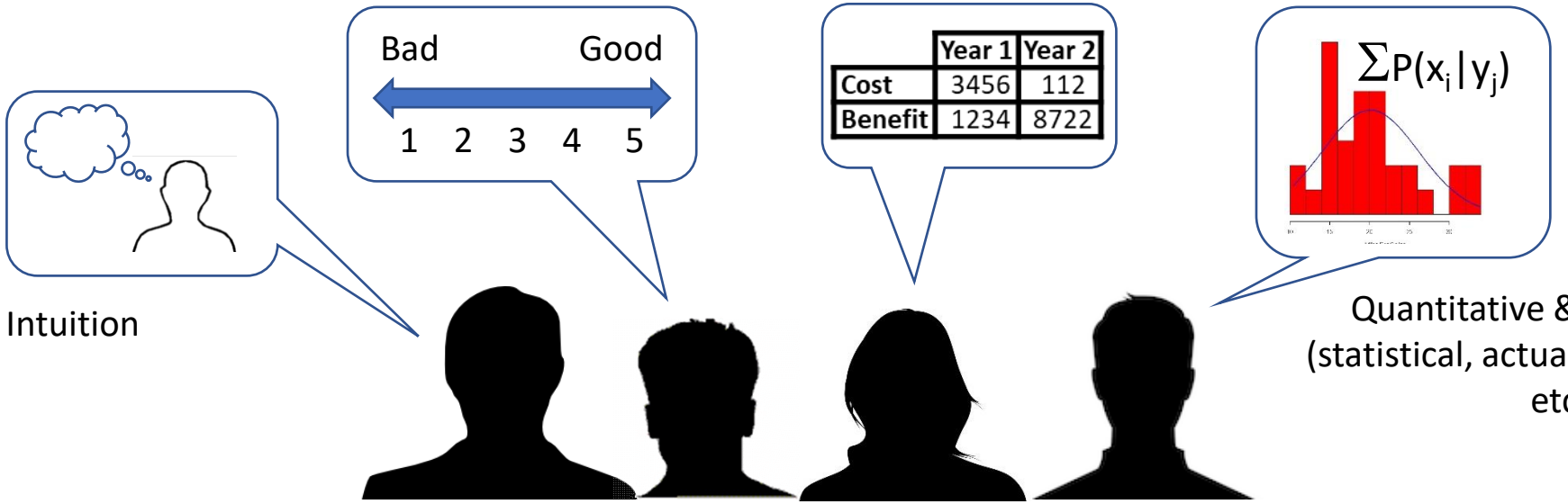
Answer: How you measure risk.

Introduction

Types of Measurement Methods

Qualitative
(soft scores or “high/medium/low”)

Accounting-style
Cost estimate analysis
(point estimates, deterministic)



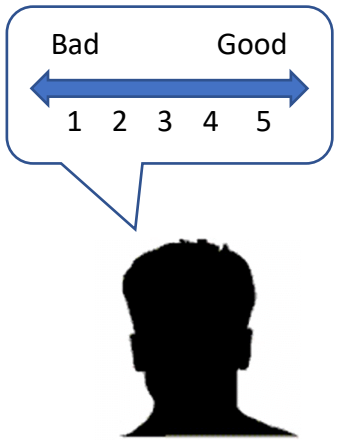
Expert Intuition

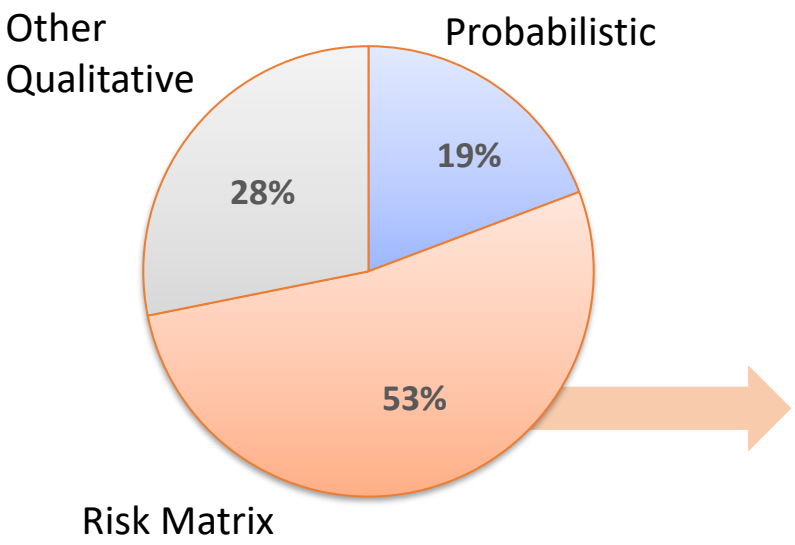
Quantitative & Probabilistic
(statistical, actuarial, simulations, etc.)

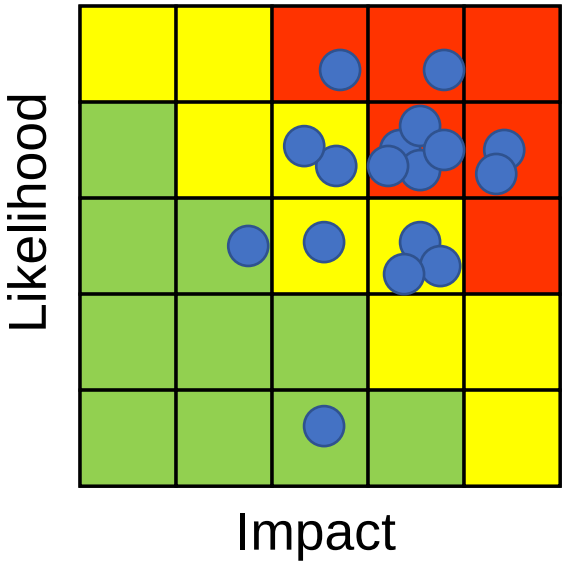
Do “Scores” and “Scales” Work?

The Current Most Popular Method

Share of Methods Used in Cybersecurity Risk Assessment

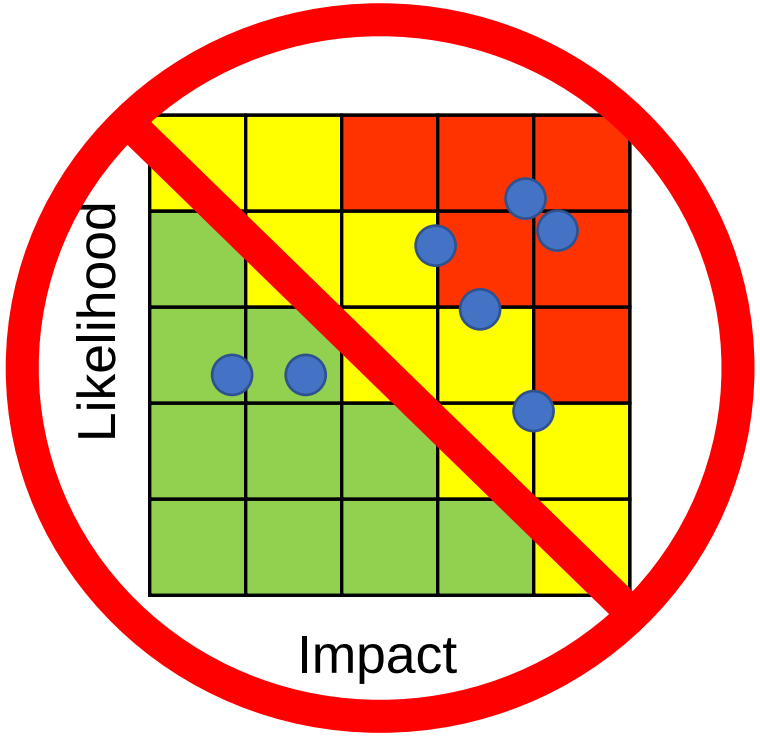






Do “Scores” and “Scales” Work?

The Ubiquitous Risk Matrix



“Risk Matrices should not be used for decisions of any consequence”

…sis 28, no. 2 (2008).

What’s Wrong with Risk Matrices?

L. A. Cox, Jr.

…ority …on

“[Risk Matrices] can be worse than useless”

Society of Petroleum Engineers Economics &Management 6, no. 2 (April 2014): 56–66.

The Risk of Using Risk Matrices

P. Thomas, R. Bratvold, and J. E. Bickel

Abstract

The risk matrix (RM) is a widely espoused approach to assess and analyze risks in the oil & gas (O&G) industry. RMs have been implemented throughout that industry and are extensively used in risk-management contexts. This is evidenced by numerous SPE papers documenting RMs as the primary risk management tool. Yet, despite this extensive use, the key question remains to be addressed: Does the use of RMs guide us to make optimal (or even better) risk-management decisions?

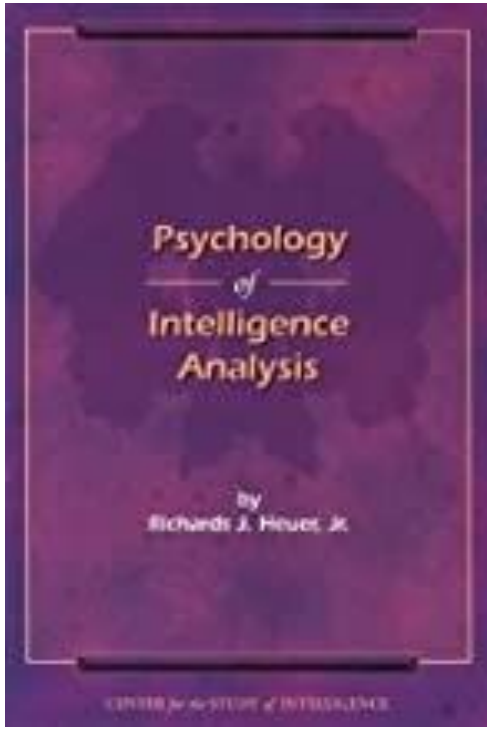
Do “Scores” and “Scales” Work?

How do we know what works?

“Intelligence analysts should be self-conscious about their reasoning processes. They should think about how they make judgments and reach conclusions, not just about the judgments and conclusions themselves.”

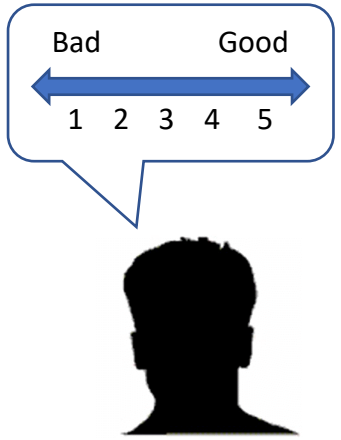
Dick Heuer, *The Psychology of Intelligence Analysis*

Meta-Decision Criteria: Is there real evidence, scientifically measured, that shows that one method is better than another?



Do “Scores” and “Scales” Work?

Unintended consequences of simple scoring methods



Climatic Change (2012) 113:181–200
DOI 10.1007/s10584-011-0330-3

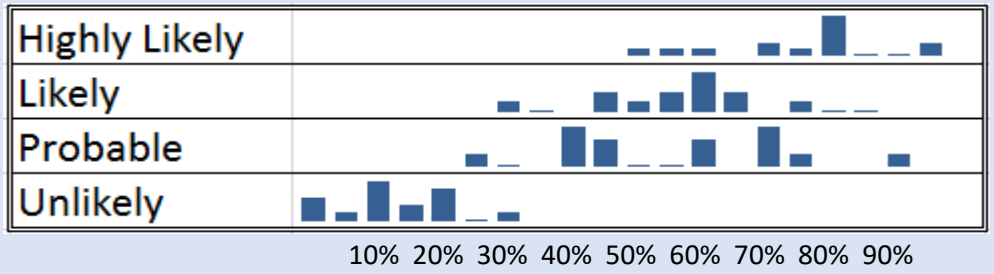
Effective communication of uncertainty in the IPCC reports

David V. Budescu · Han-Hui Por · Stephen B. Broomell

Received: 21 June 2010 / Accepted: 19 October 2011 / Published online: 23 November 2011

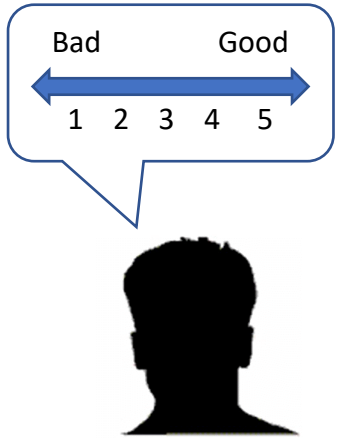
Abstract The Intergovernmental Panel on Climate Change (IPCC) publishes periodical

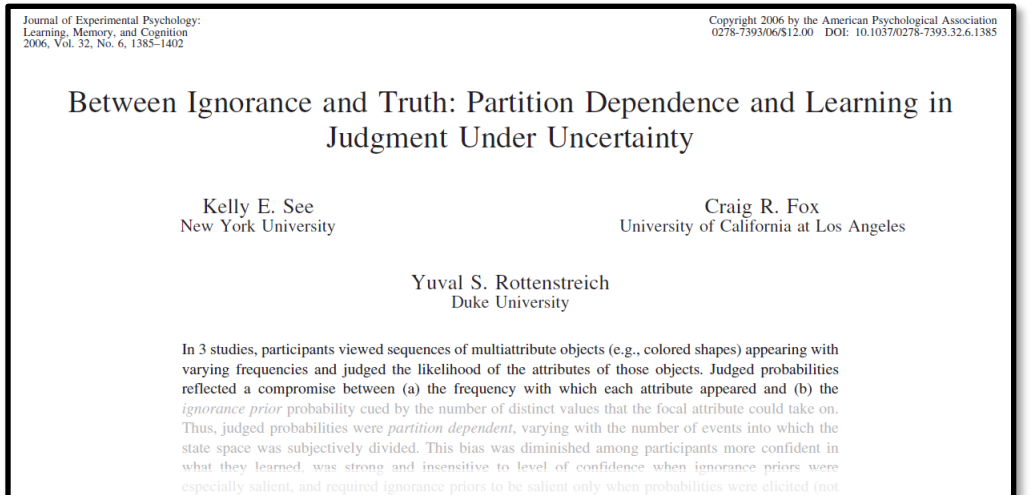
David Budescu and Dick Heuer (separately) Researched the “illusion of communication” regarding interpretations of verbal labels for probabilities



Do “Scores” and “Scales” Work?

Unintended consequences of simple scoring methods





Journal of Experimental Psychology:
Learning, Memory, and Cognition
2006, Vol. 32, No. 6, 1385–1402

0278-7393/06/$12.00 DOI: 10.1037/0278-7393.32.6.1385

Between Ignorance and Truth: Partition Dependence and Learning in Judgment Under Uncertainty

Kelly E. See
New York University

Craig R. Fox
University of California at Los Angeles

Yuval S. Rottenstreich
Duke University

In 3 studies, participants viewed sequences of multiattribute objects (e.g., colored shapes) appearing with varying frequencies and judged the likelihood of the attributes of those objects. Judged probabilities reflected a compromise between (a) the frequency with which each attribute appeared and (b) the *ignorance prior* probability cued by the number of distinct values that the focal attribute could take on. Thus, judged probabilities were *partition dependent*, varying with the number of events into which the state space was subjectively divided. This bias was diminished among participants more confident in what they learned, was strong and insensitive to level of confidence when ignorance priors were especially salient, and required ignorance priors to be salient only when probabilities were elicited (not

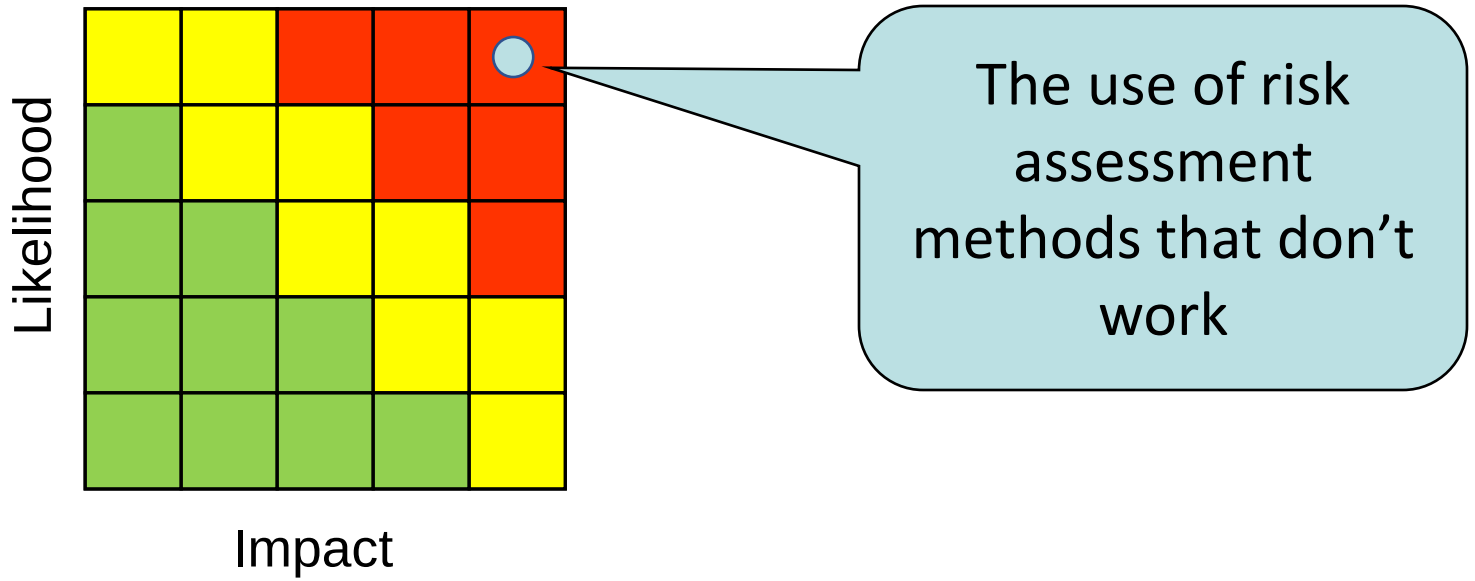
Craig R. Fox showed how arbitrary features of how scales are partitioned effects responses.

Example:

If “1” on a 5-point impact scale means “less than $1 million loss”, the share of that response is affected by the partition of *other* choices.

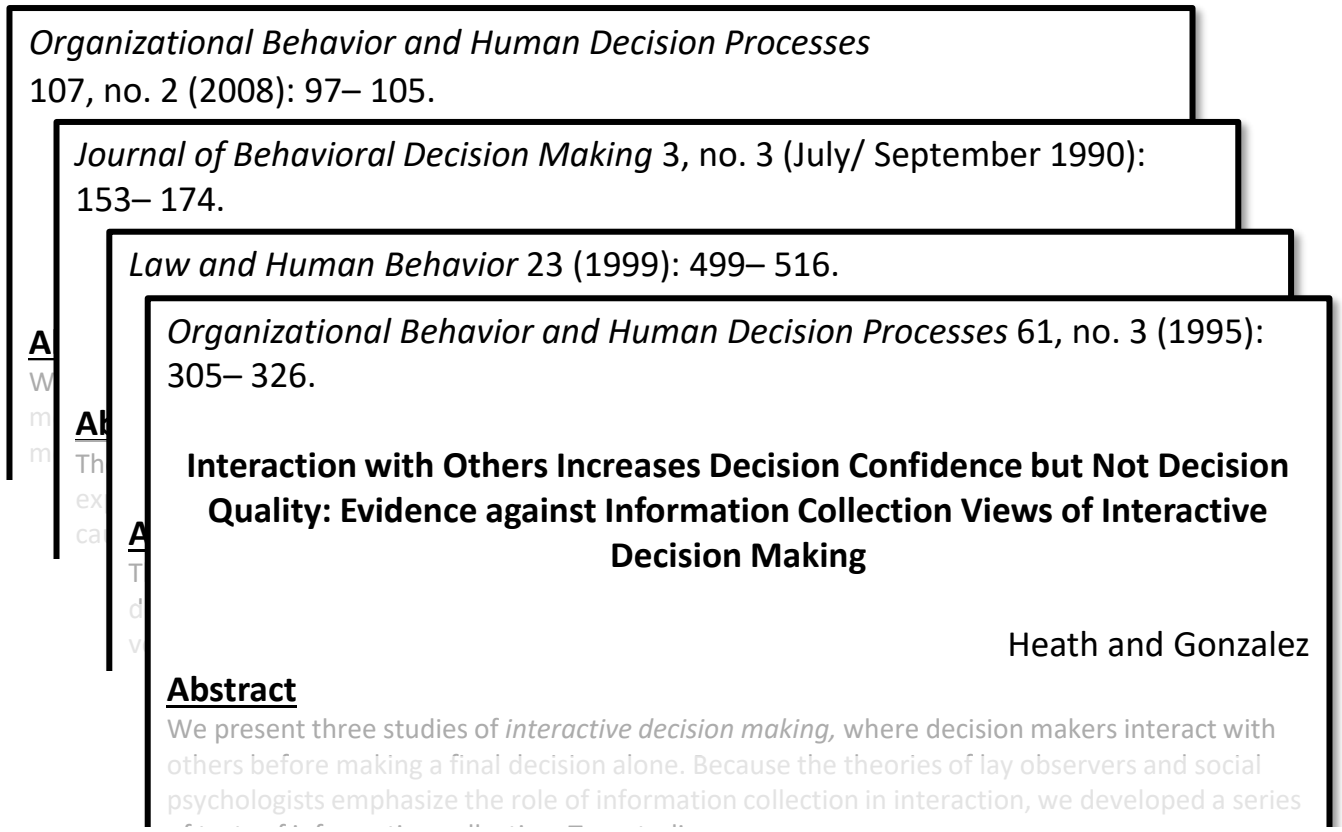
Do “Scores” and “Scales” Work?

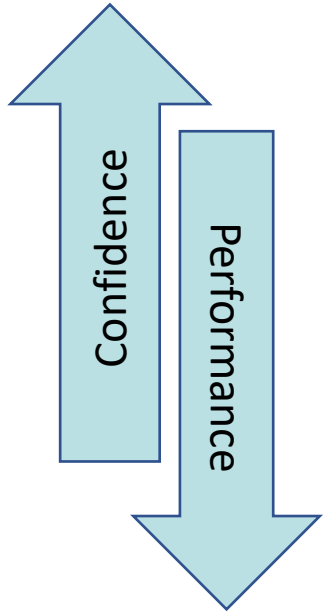
The Only Risk Matrix You Need



The Analysis Placebo

Confidence in decision making methods is detached from performance





The Meta Decision

How to Build a Method That Works

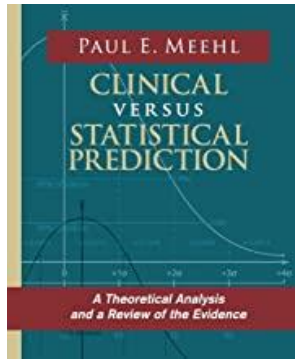
- Start with components that work.
- Don’t rely on anecdotes, testimonials or claims of “best practices” as evidence of working.
- If you can’t answer “What is the probability of losing more than X in the next 12 months due to event Y?” then you aren’t doing risk analysis.

Experts vs. Algorithms

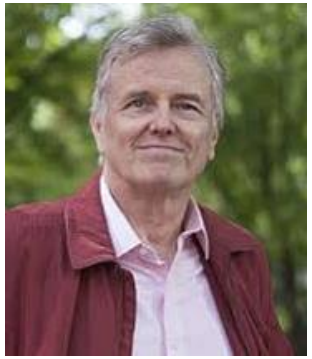
What the research says about statistical methods vs. Subject Matter Experts

Paul Meehl assessed 150 studies comparing experts to statistical models in many fields (sports, prognosis of liver disease, etc.).

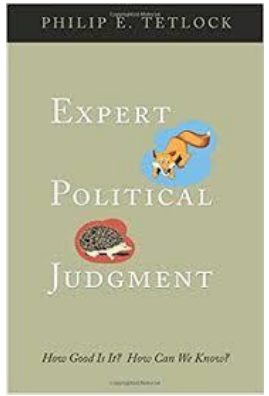
"There is no controversy in social science which shows such a large body of qualitatively diverse studies coming out so uniformly in the same direction as this one."



Philip Tetlock tracked a total of over 82,000 forecasts from 284 experts in a 20-year study covering politics, economics, war, technology trends and more.



"It is impossible to find any domain in which humans clearly outperformed crude extrapolation algorithms, less still sophisticated statistical ones."



What Measuring Risk Looks Like

Is Risk Analysis Actually Supporting Decisions?

- If risks and mitigation strategies were quantified in a meaningful way, decisions could be supported.
- In order to compute an ROI on mitigation decisions, we need to quantify likelihood, monetary impact, cost, and effectiveness.

	Expected Loss/Yr	Cost of Control	Control Effectiveness	Return on Control	Action
DB Access	$24.7M	$800K	95%	2,832%	**Mitigate**
Physical Access	$2.5M	$300K	99%	727%	**Mitigate**
Data in Transit	$2.3M	$600K	95%	267%	**Mitigate**
Network Access Control	$2.3M	$400K	30%	74%	**Mitigate**
File Access	$969K	$600K	90%	45%	**Monitor**
Web Vulnerabilities	$409K	$800K	95%	-51%	**Track**
System Configuration	$113K	$500K	100%	-77%	**Track**

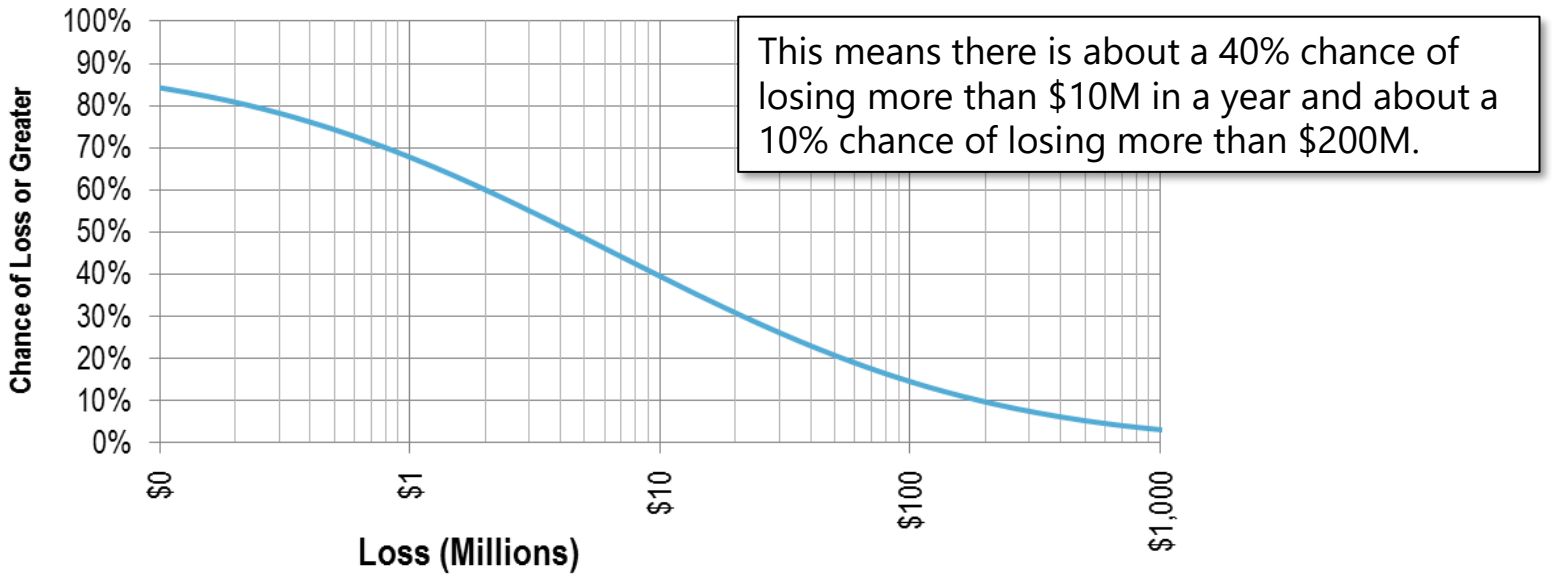
What Measuring Risk Looks Like

The Loss Exceedance Curve

What if we could measure risk more like an actuary? For example, “The probability of losing more than $10 million due to security incidents in 2016 is 16%.”

What if we could prioritize security investments based on a “Return on Mitigation”?

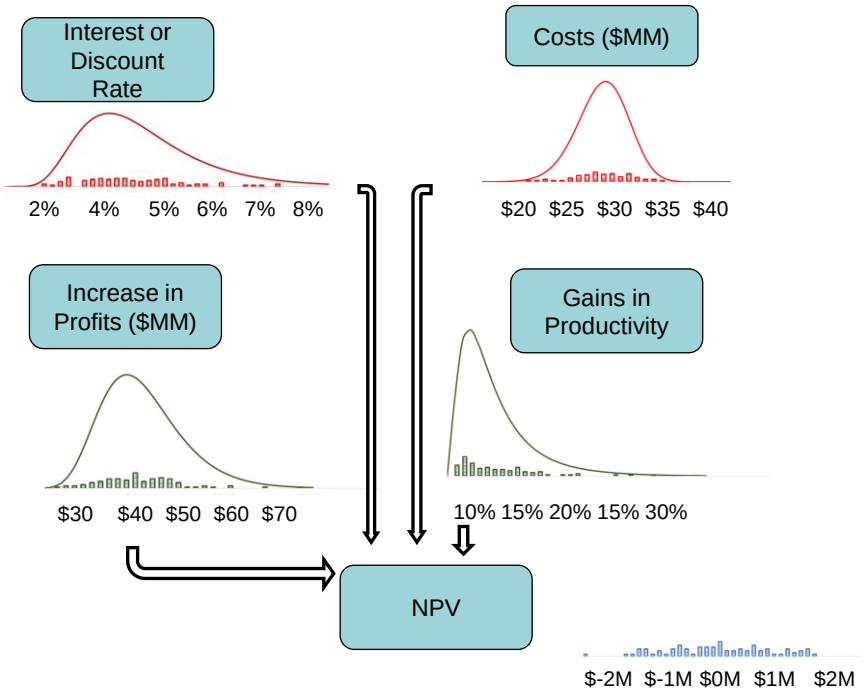
	Expected Loss/Yr	Cost of Control	Control Effectiveness	Return on Control	Action
DB Access	$24.7M	$800K	95%	2,832%	Mitigate
Physical Access	$2.5M	$300K	99%	727%	Mitigate
Data in Transit	$2.3M	$600K	95%	267%	Mitigate
Network Access Control	$2.3M	$400K	30%	74%	Mitigate
File Access	$969K	$600K	90%	45%	Monitor
Web Vulnerabilities	$409K	$800K	95%	-51%	Track
System Configuration	$113K	$500K	100%	-77%	Track



This means there is about a 40% chance of losing more than $10M in a year and about a 10% chance of losing more than $200M.

The Method of Measurement

Monte Carlo: How to Model Uncertainty in Decisions



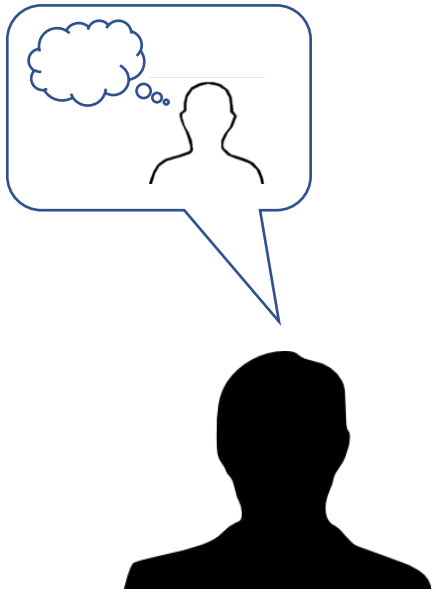
What Published Research Says
(See sources slide for details)

- Psychologists showed that simple decomposition greatly reduces estimation error for estimating the most uncertain variables.
- In the oil industry there is a correlation between the use of quantitative risk analysis methods and financial performance.
- Data at NASA from over 100 space missions showed that Monte Carlo simulations and historical data beat softer methods for estimating cost and schedule risks.

The Method of Measurement

Why Does Our Risk Tolerance Change?

Decision makers are also inconsistent regarding their own aversion to risk.



Neuron Vol. 47, (2005): 763–770

The Neural Basis of Financial Risk Taking

Camelia M. Kuhnen and Brian Knutson

Journal of Personality and Social Psychology
2001, Vol. 81, No. 1, 146–159

Copyright 2001 by the American Psychological Association, Inc.
0022-3514/01/$5.00 DOI: 10.1037//0022-3514.81.1.146

Fear, Anger, and Risk

Jennifer S. Lerner
Carnegie Mellon University

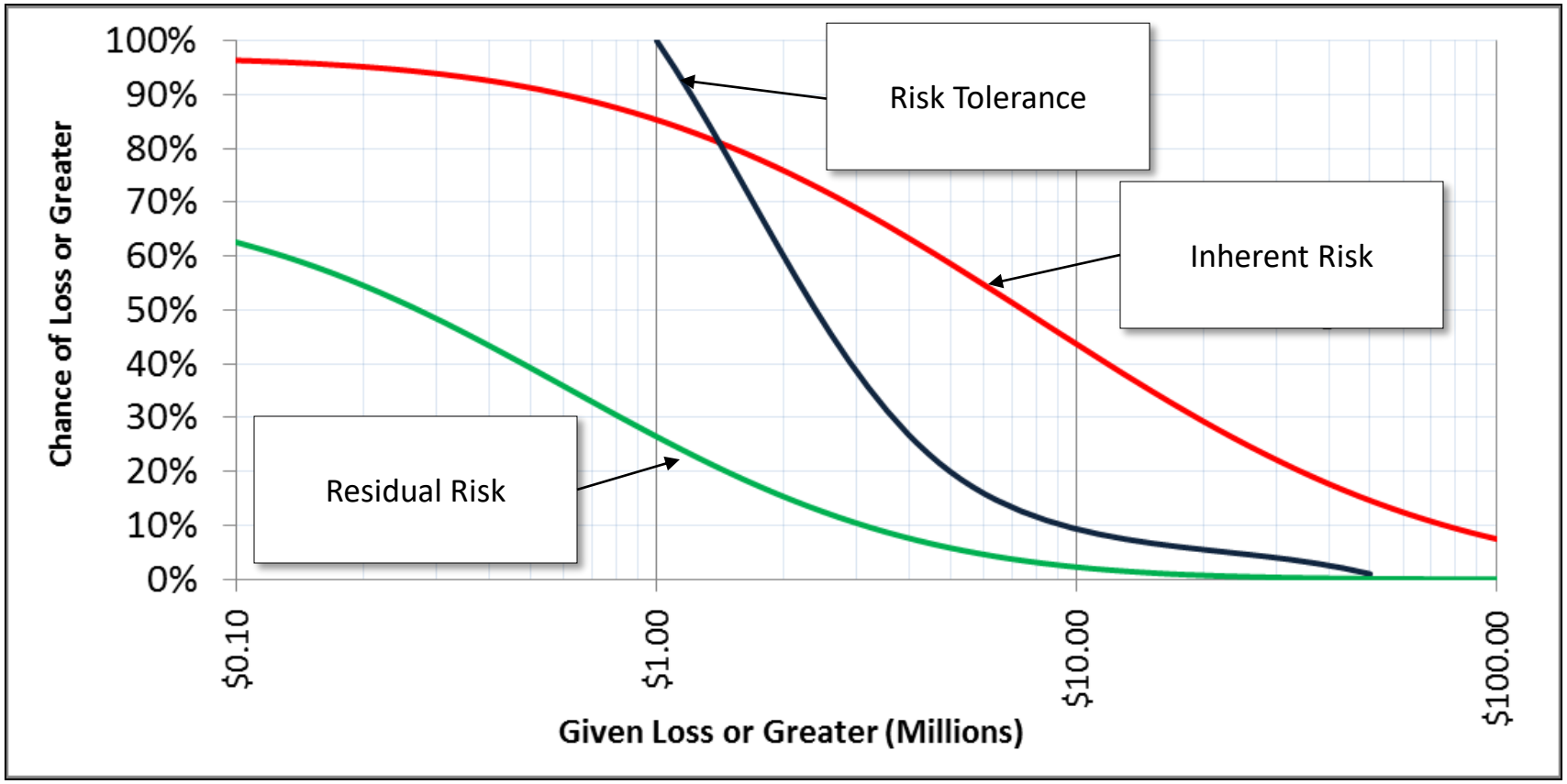
Dacher Keltner
University of California, Berkeley

Factor	Risk Aversion
Being around smiling people	↓
Recalling an event causing fear	↑
Recalling an event causing anger	↓
A recent win in an unrelated decision	↓
A recent loss in an unrelated decision	↑

The Method of Measurement

Loss Exceedance Curves: Before and After

How do we show the risk exposure after applying available mitigations?



What Measuring Risk Looks Like

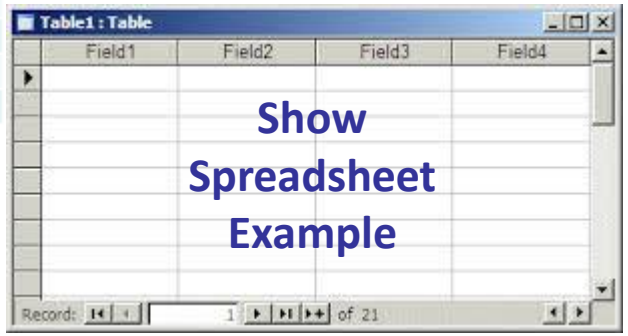
A Simple “One-For-One Substitution”

Each of these examples can be found on
https://www.howtomeasureanything.com/riskmanagement/

Event	Event Probability (per Year)	Impact (90% Confidence Interval)		Random Result (zero when the event did not occur)
		Lower Bound	Upper Bound	
AA	.1	$50,000	$500,000	0
AB	.05	$100,000	$10,000,000	$8,456,193
AC	.01	$200,000	$25,000,000	0
AD	.03	$100,000	$15,000,000	0
AE	.05	$250,000	$30,000,000	0
AF	.1	$200,000	$2,000,000	0
AG	.07	$1,000,000	$10,000,000	$2,110,284
AH	.02	$100,000	$15,000,000	0
ZM	.05	$250,000	$30,000,000	0
ZN	.01	$1,500,000	$40,000,000	0
			Total:	$23,345,193

Each “Dot” on a risk matrix can be better represented as a row on a table like this

The output can then be represented as a Loss Exceedance Curve.



Obstacles to Better Methods

Obstacles: Why Better Methods Are Not Adopted

So Why Don't We Use More Quantitative Methods?

Commonly stated reasons for not using quantitative methods

Have you heard (or said) any of these?

"We don't have sufficient data"

"Risk management is too complex to model."

"Each situation is too unique and complex to apply scientific analysis of historical data."

"How do you know you have all the variables?"

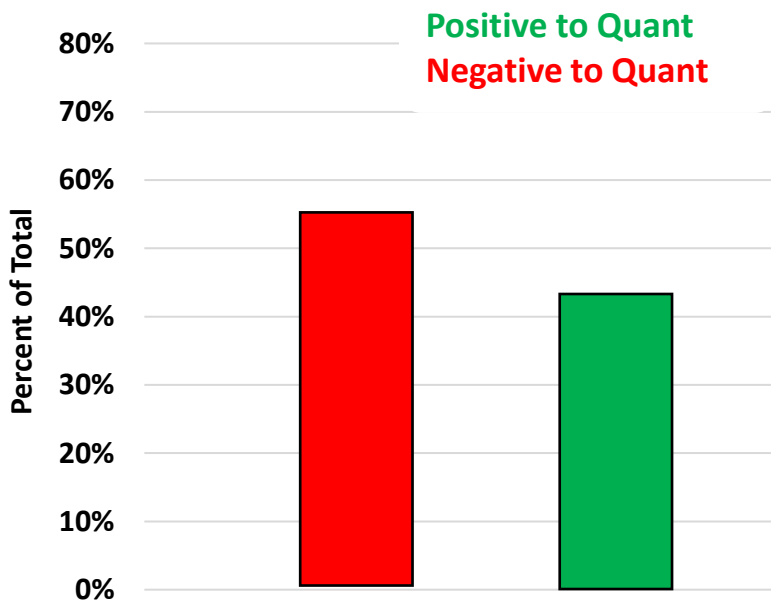
The implied (and unjustified) conclusion from each of these is….

"Therefore, we are better off relying on our experience."

So Why Don’t We Use More Quantitative Methods?

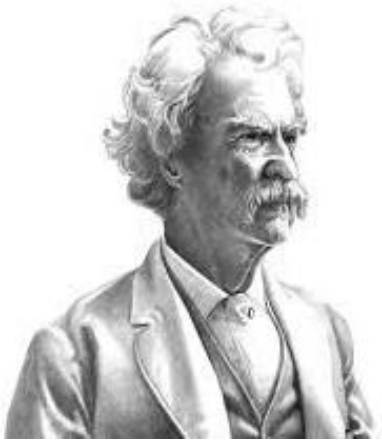
The Main Obstacle to Quantitative Methods

Another finding in the same survey: Strong opinions against “quant” are associated with poor stats understanding.



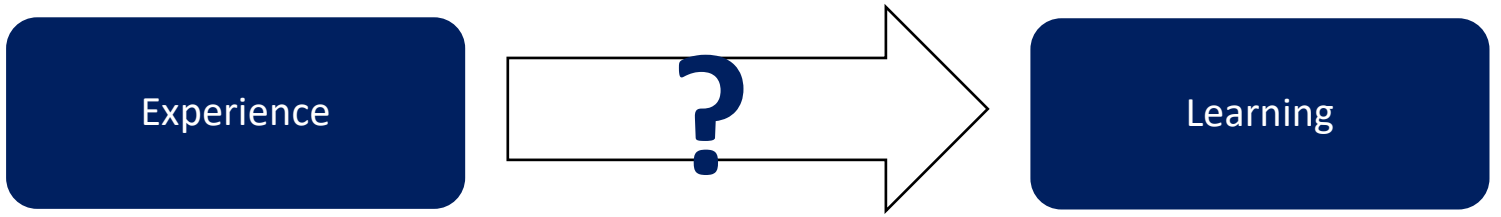
“It’s not what you don’t know that will hurt you, it’s what you know that ain’t so.”

Mark Twain



Experience vs. Learning

Why It's Hard to Learn



- "Experience is inevitable, learning is not." Paul Schoemaker
- Kahneman and Klein differentiate high and low validity tasks based on feedback:

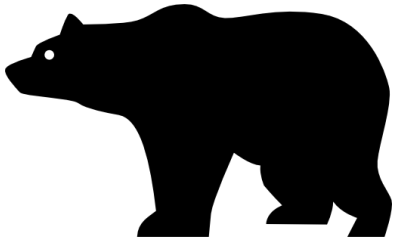
- Consistent
- Immediate
- Unambiguous

Irrational Bias Against Algorithms

A Double Standard

Don't commit the classic "Beat the Bear" fallacy.

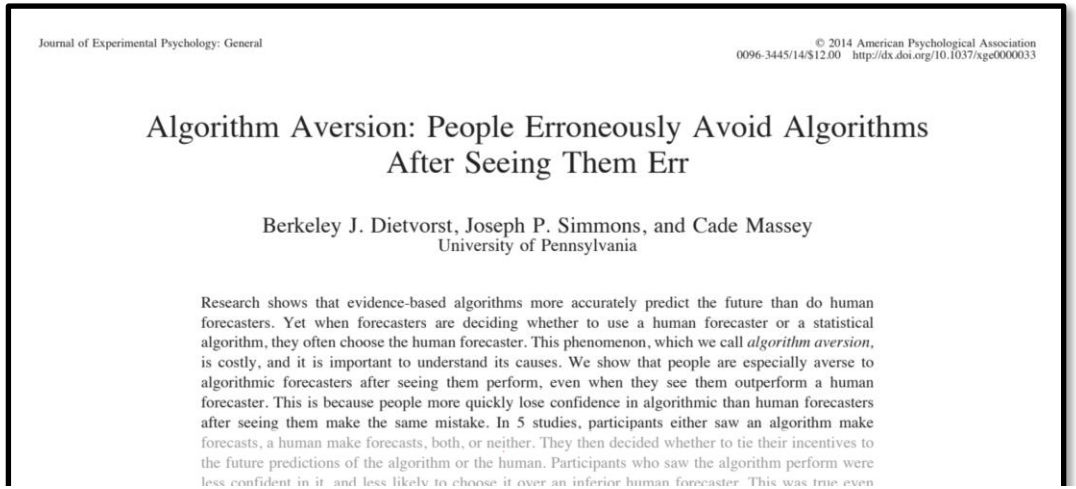
Exsupero Ursus



A common form of the ***Exsupero Ursus*** fallacy:
"The quantitative model must have

1) All the variables
2) All the data
3) All the right distributions and correlations
4) All the above

If not, default to a measurably worse method.



Journal of Experimental Psychology: General

0096-3445/14/$12.00 http://dx.doi.org/10.1037/xge0000033

Algorithm Aversion: People Erroneously Avoid Algorithms After Seeing Them Err

Berkeley J. Dietvorst, Joseph P. Simmons, and Cade Massey
University of Pennsylvania

Research shows that evidence-based algorithms more accurately predict the future than do human forecasters. Yet when forecasters are deciding whether to use a human forecaster or a statistical algorithm, they often choose the human forecaster. This phenomenon, which we call *algorithm aversion*, is costly, and it is important to understand its causes. We show that people are especially averse to algorithmic forecasters after seeing them perform, even when they see them outperform a human forecaster. This is because people more quickly lose confidence in algorithmic than human forecasters after seeing them make the same mistake. In 5 studies, participants either saw an algorithm make forecasts, a human make forecasts, both, or neither. They then decided whether to tie their incentives to the future predictions of the algorithm or the human. Participants who saw the algorithm perform were less confident in it, and less likely to choose it over an inferior human forecaster. This was true even

The Three Misconceptions Behind Any Perceived "Immeasurable"

The Illusions of Immeasurability

CONCEPT of Measurement	The definition of measurement itself is widely misunderstood.
OBJECT of Measurement	The thing being measured is not well defined.
METHOD of Measurement	Many procedures of empirical observation are misunderstood.

The Three Misconceptions Behind Any Perceived “Immeasurable”

The Concept of Measurement

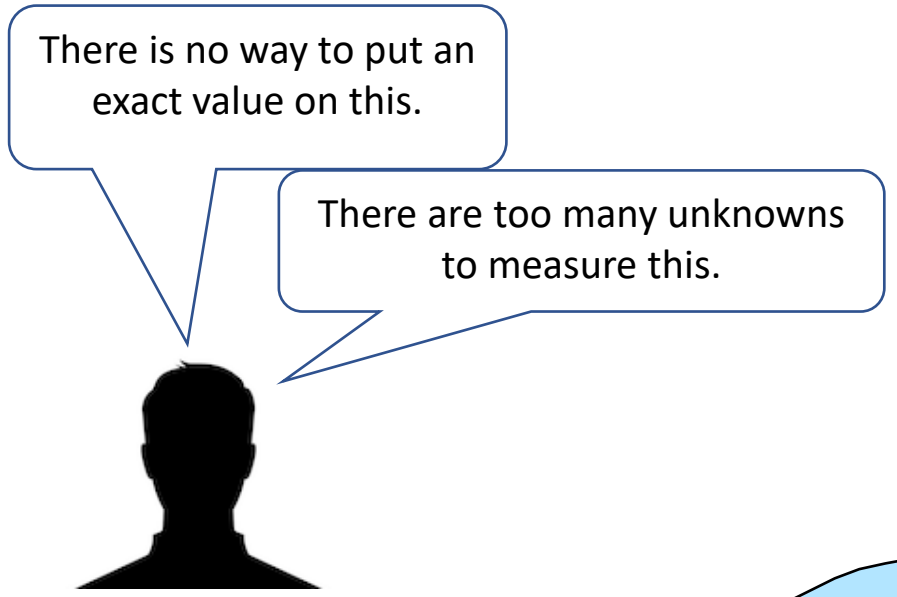
CONCEPT of Measurement	The definition of measurement itself is widely misunderstood.
OBJECT of Measurement	The thing being measured is not well defined.
METHOD of Measurement	Many procedures of empirical observation are misunderstood.

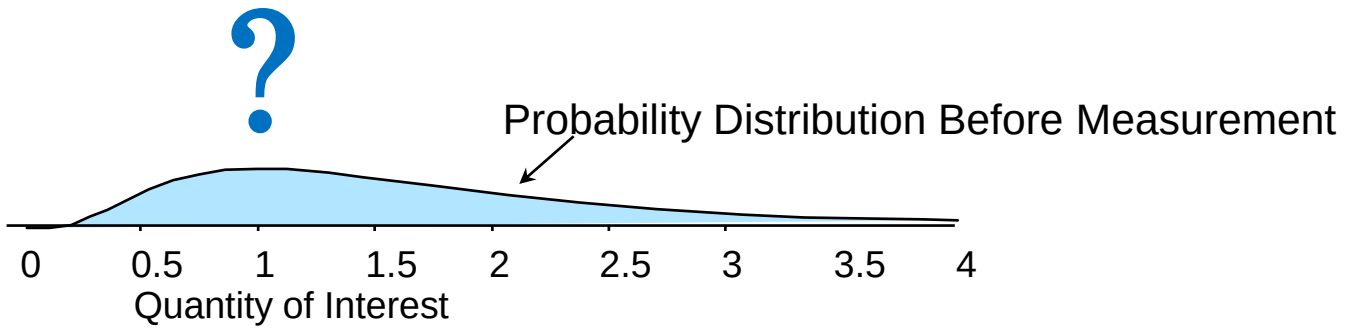
The Concept of Measurement

What Measurement Really Means

It's not a point value.

Measurement: a quantitatively expressed reduction in uncertainty based on observation.



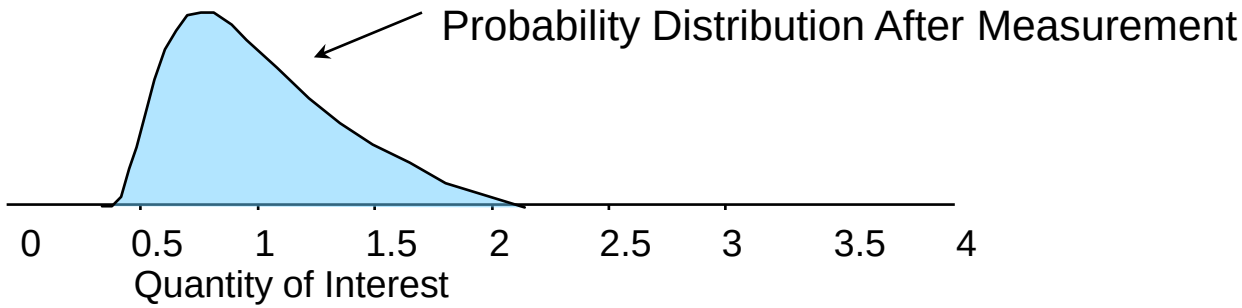


The Concept of Measurement

What Measurement Really Means

It's not a point value.

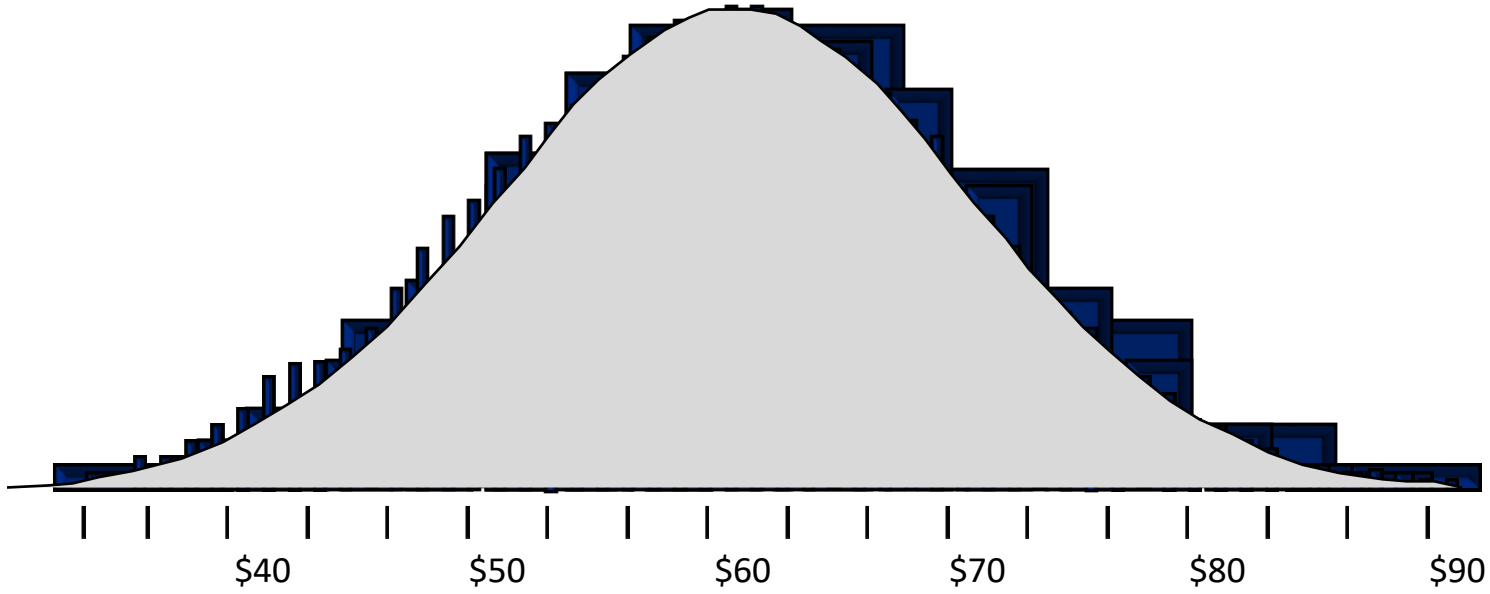
Measurement: a quantitatively expressed reduction in uncertainty based on observation.



The Concept of Measurement

Constructing a Distribution

- Uncertainty about “either/or” events are expressed as “discrete” probabilities (e.g. “35%).
- Uncertainty about continuous values can still be thought of as sets of discrete probabilities.



Calibrated Experts

What the research says about Subject Matter Experts

"Overconfident professionals sincerely believe they have expertise, act as experts and look like experts. You will have to struggle to remind yourself that they may be in the grip of an illusion."

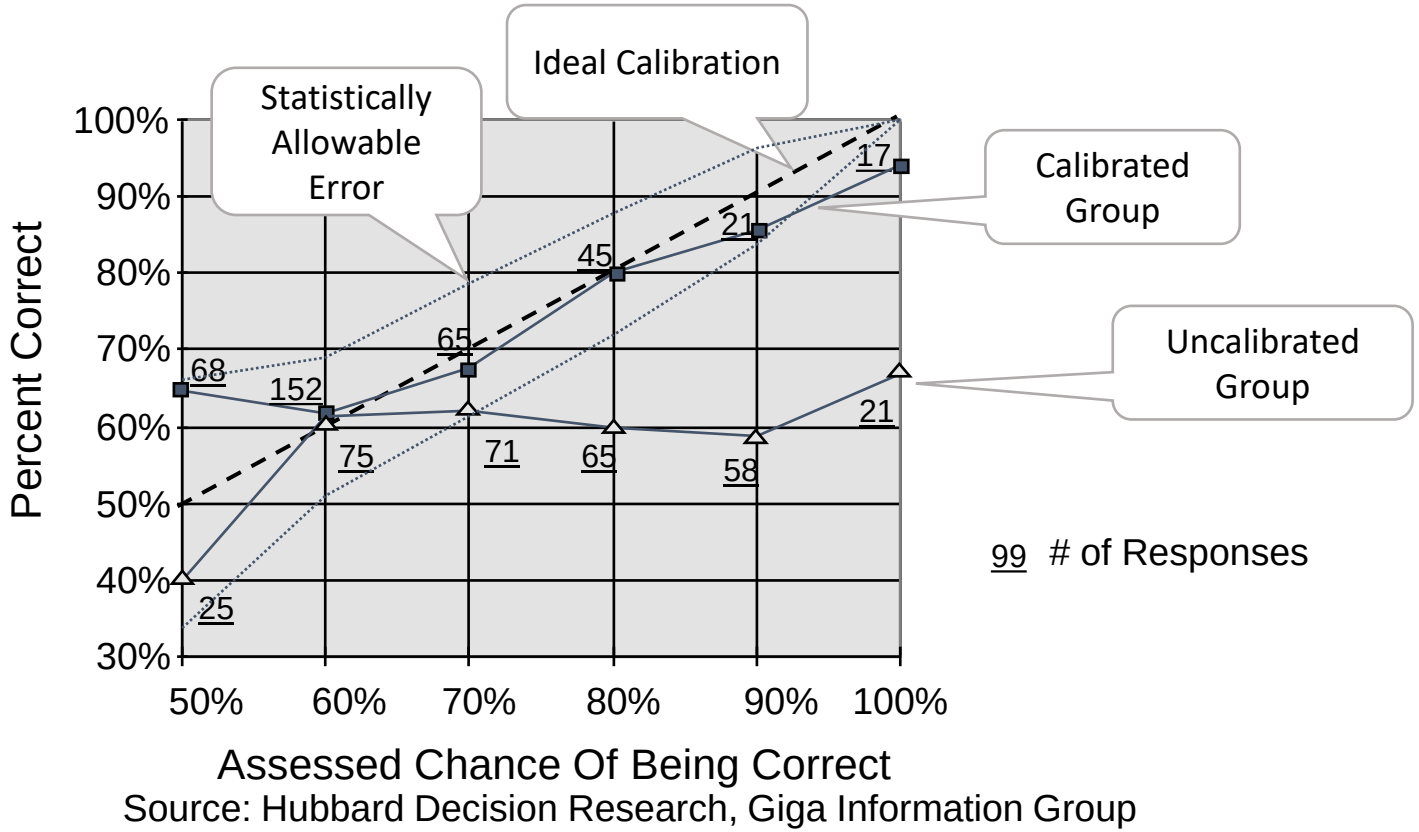
Daniel Kahneman, Psychologist, Economics Nobel

- Decades of studies show that most managers are statistically "overconfident" when assessing their own uncertainty.
- Studies also show that measuring *your own* uncertainty about a quantity is a general skill that <u>can be taught</u> with a ***measurable*** improvement.

The Method of Measurement

Training Experts to Give Calibrated Probabilities

Training can “calibrate” people so that of all the times they say they are 90% confident, they will be right 90% of the time.



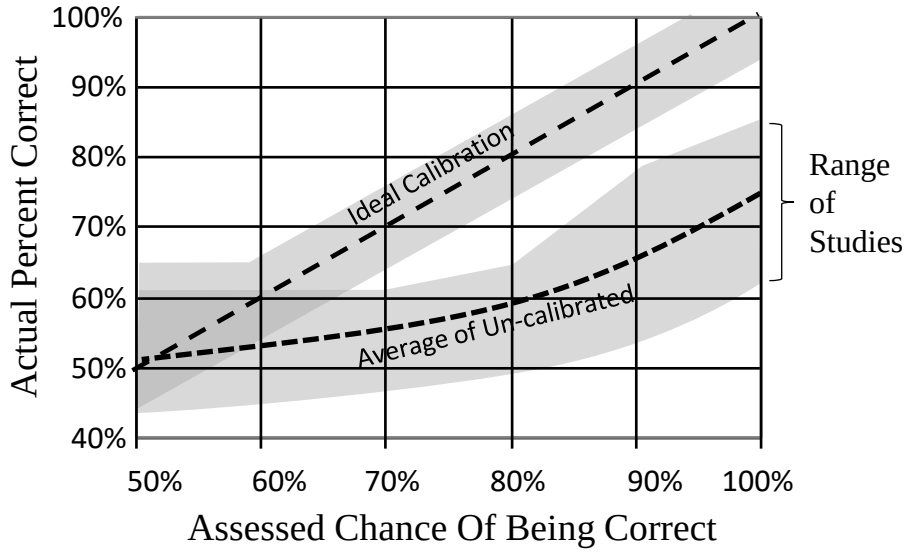
Source: Hubbard Decision Research, Giga Information Group

The Method of Measurement

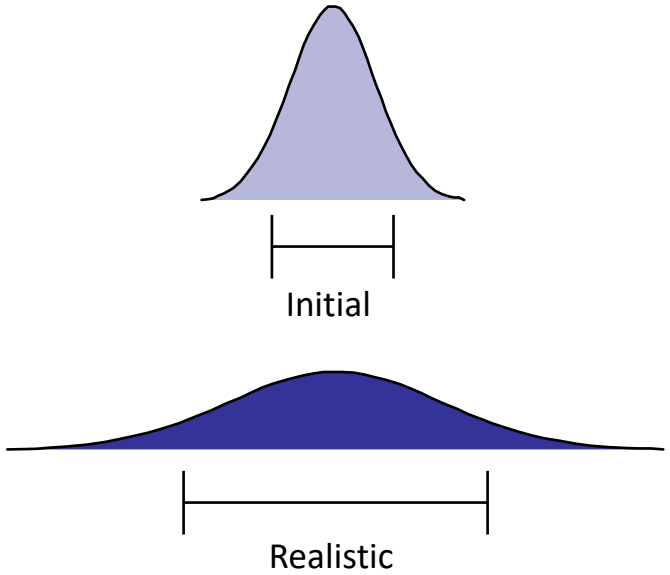
Overconfidence in Ranges

The same training methods apply to the assessment of uncertain ranges for quantities like the duration of a future outage, the records compromised in a future breach, etc.

Binary Events
(It happens or not, like a chance of data breach)



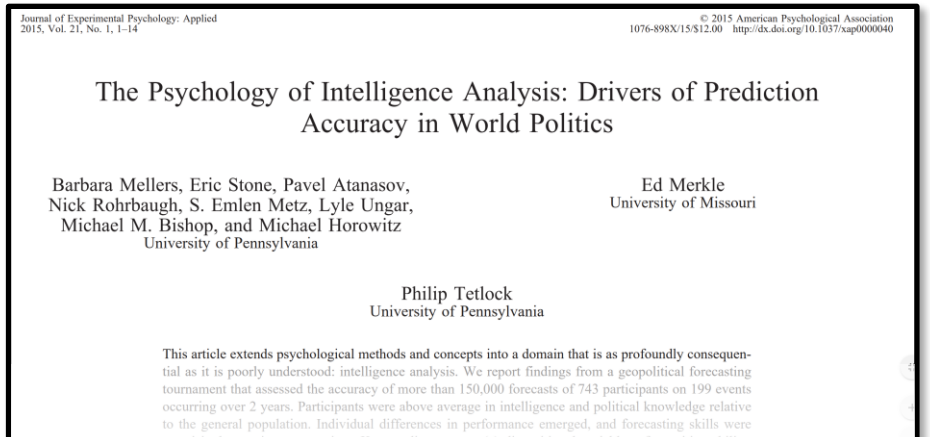
90% Confidence Interval
(For continuous values, like impact)



The Method of Measurement

Improving Expert Forecasts

- Tetlock also looked at what improved *forecasting.*
- He tracked 743 individuals who made at least 30 forecasts each over a 2-year period.
- He determined factors that made the biggest difference in the performance of forecasting.



Journal of Experimental Psychology: Applied
2015, Vol. 21, No. 1, 1–14

1076-898X/15/$12.00 http://dx.doi.org/10.1037/xap0000040

The Psychology of Intelligence Analysis: Drivers of Prediction Accuracy in World Politics

Barbara Mellers, Eric Stone, Pavel Atanasov, Nick Rohrbaugh, S. Emlen Metz, Lyle Ungar, Michael M. Bishop, and Michael Horowitz
University of Pennsylvania

Ed Merkle
University of Missouri

Philip Tetlock
University of Pennsylvania

This article extends psychological methods and concepts into a domain that is as profoundly consequential as it is poorly understood: intelligence analysis. We report findings from a geopolitical forecasting tournament that assessed the accuracy of more than 150,000 forecasts of 743 participants on 199 events occurring over 2 years. Participants were above average in intelligence and political knowledge relative to the general population. Individual differences in performance emerged, and forecasting skills were

Probabilistic Training

- Subjects were trained in basic inference methods, using reference classes, and avoiding common errors and biases.

Teams and Belief Updating

- Teams deliberated more and individuals were willing to update beliefs based on new information.

Selecting the Best

- Brains matter. Both topic expertise and overall IQ were the best predictors of performance.

The Three Misconceptions Behind Any Perceived “Immeasurable”

The Object of Measurement

CONCEPT of Measurement	The definition of measurement itself is widely misunderstood.
OBJECT of Measurement	The thing being measured is not well defined.
METHOD of Measurement	Many procedures of empirical observation are misunderstood.

The Object of Measurement

The Importance of Defining a Measurement

- If a thing seems like an immeasurable “intangible” it may just be ill-defined.
- Often, if we can define what we mean by a certain “intangible” we find ways to measure it.
- Examples: Brand image, Security, Safety, etc.

The Object of Measurement

Clarifying the Problem

1. Why do you care? (What decision could depend on the outcome of this measurement?)
2. What do you see when you see more of it? (Describe it in terms of observable consequences, then units of measure.)
3. How much do you know about it now?
4. At what point will the value make a difference?
5. How much is additional information worth?

If you can answer the first three, you can usually compute the last two.

The Three Misconceptions Behind Any Perceived “Immeasurable”

The Method of Measurement

CONCEPT of Measurement	The definition of measurement itself is widely misunderstood.
OBJECT of Measurement	The thing being measured is not well defined.
METHOD of Measurement	Many procedures of empirical observation are misunderstood.

The Method of Measurement

The Urn of Mystery

THE *URN OF MYSTERY* PROBLEM

- There is a warehouse full of urns.
- Each urn is filled with over a million marbles, each of which are red or green.
- The proportion of red marbles in each urn is unknown – it could be anything between 0% and 100% and all possibilities are equally likely.

Questions:

If you randomly select a single marble from a randomly selected urn, what is the chance it is red?

If the marble you draw is red, what is the chance the majority of marbles are red?

If you draw 8 marbles and all are green, what is the chance that the next one you draw will be red?

The Method of Measurement

Intuitions About Samples Are Wrong

- There are widely held misconceptions about probabilities and statistics – especially if they vaguely remember some college stats.
- These misconceptions lead many experts to believe they lack data for assessing uncertainties or they need some ideal amount before anything can be inferred.

"Our thesis is that people have strong intuitions about random sampling…these intuitions are wrong in fundamental respects...[and] are shared by naive subjects and by trained scientists"
Amos Tversky and Daniel Kahneman, Psychological Bulletin, 1971

The Method of Measurement

The Rule of Succession

Danny Kahneman

A reference class is a population from which you draw observations of events to determine their frequency. Your "reference class" is much larger than you.

You can start by making as few assumptions as possible – your "baseline" uses only your reference class

Pierre-Simon Laplace
1749-1827

Laplace's "rule of succession": Given a population of reference class, like company-years, where some number of events occurred:

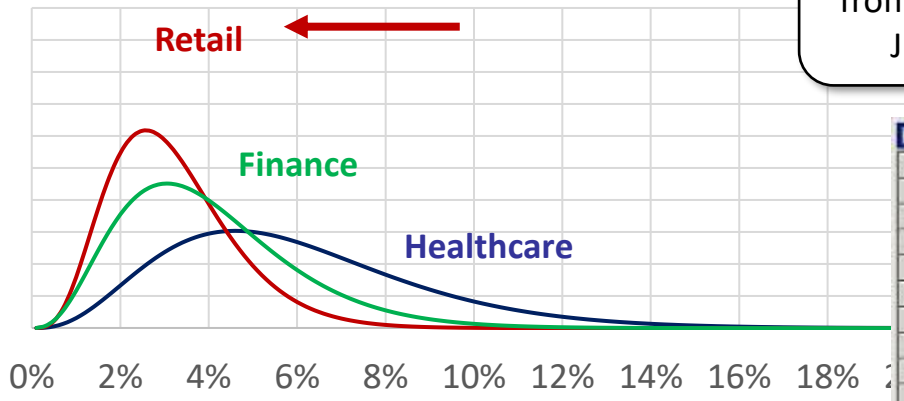
- Chance of X (per year, per draw, etc.) =(1+hits)/(2+hits+misses)

The Method of Measurement

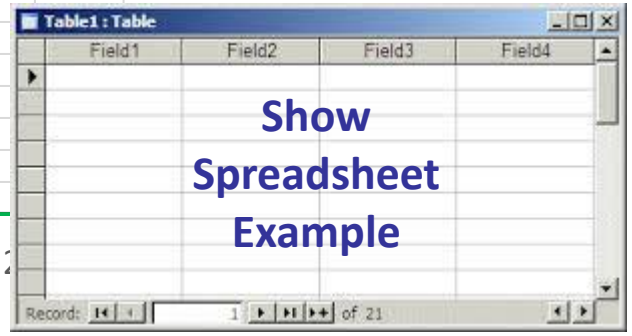
Estimating Breach Rate w/ “Reference Classes”

- You may not have had a particular major event type, but others have.
- You have relatively few examples of major, reported breaches in each industry.
- There is a statistical method for estimating the frequency of events based on small samples.

Distribution of Breach Frequency by Industry (Not Current Data)



Out of 98 Retail had 3 breaches from Jan 2014 to June 2015



Annual Breach Frequency per Organization

The Method of Measurement

Bayesian Methods

- "Bayesian" methods in statistics use new information to update prior knowledge.

Bayes Theorem: $$P(X|Y) = \frac{P(X)P(Y|X)}{P(Y)} = \frac{P(X)P(Y|X)}{\sum_i P(Y|X_i)\,P(X_i)}$$

P(X) = the probability of X

P(X|Y) = the probability of X given the condition Y

$\sum_i P(Y \mid X_i)\,P(X_i)$ = the sum of the probability of Y under each possible condition

- The Simplest Measurement Method — It turns out that calibrated people are already mostly "instinctively Bayesian".
  - Assess your initial subjective uncertainty with a calibrated probability
  - Gather and study new information
  - Give another subjective calibrated probability assessment

The Method of Measurement

Final Thoughts

It's Been Measured Before	• Important topics have often been measured already.
You Have More Data Than You Think	• Define a reference class – don't commit the reference class fallacy.
You Need Less Data Than You Think	• Question your intuition about how and whether messy and incomplete data is.

Example Spreadsheets for many of the calculations mentioned can be found at www.howtomeasureanything.com

Summary

Your Real Job in Risk Assessment & Management

You are a creator and manager of models – not just a “down in the weeds” estimator/forecaster/decision maker.

- You evaluate data from external literature and reference classes.
- You frequently record internal estimates and decisions, whether large or small.
- You evaluate performance, continuously improve, and look for the best forecasters.
- This holds for models of expert intuition (including your own) and complex calculations.
- You gradually replace areas of pure intuition with tested calculations.

Summary

Questions to Ask about Risk Management In General

1. How are measurement instruments (including experts) calibrated?
2. How are probabilities updated with empirical data?
3. How are probabilities and impacts modeled/aggregated?
4. How are resource allocation decisions made toward mitigating risks?
5. How is the performance of method itself being measured and updated?
6. How is completeness and correctness verified?
7. How do we implement it?

Do’s and Don’ts

- Stop using risk matrices and “high, medium, low” as assessments of risk.

- Start using previously proven components:
  - probabilistic methods including Monte Carlo
  - calibrated experts
  - historical observations
  - quantified risk tolerance

Questions?

Contact:

Doug Hubbard

Hubbard Decision Research

dwhubbard@hubbardresearch.com

www.hubbardresearch.com

630 858 2788

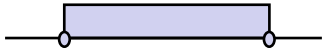
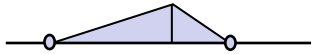
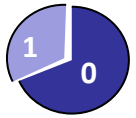
Supplementary Material

Hubbard Decision Research
2 South 410 Canterbury Ct
Glen Ellyn, Illinois 60137
www.hubbardresearch.com

Basic Distributions

Each of these examples can be found on

www.howtomeasureanything.com/cybersecurity

Distributions*	Upper & Lower Bound	Best Estimate
Normal distribution 	Represents the "90% confidence interval"	Always half-way between upper and lower bound
Lognormal distribution 	Represents the "90% confidence interval"; the absolute lower bound of a lognormal is always 0	Always a function of the upper and lower bound
Uniform distribution 	Represents the absolute (100% certain) upper and lower bounds	NA
Triangular distribution 	Represents the absolute (100% certain) upper and lower bounds	Represents the mode; the most likely value
Binary distribution 	NA	Represents the % chance of the event occurring
Beta distribution 	Generates a value between 0 and 1 based on “hits” and “misses”	The mode of a beta is (hits-1)/(hits+misses-2)

*A “●” means a “hard” stop, an “➔” arrow means unbounded

Selected Sources

- Tsai C., Klayman J., Hastie R. “Effects of amount of information on judgment accuracy and confidence” *Org. Behavior and Human Decision Processes,* Vol. 107, No. 2, 2008, pp 97-105
- Heath C., Gonzalez R. “Interaction with Others Increases Decision Confidence but Not Decision Quality: Evidence against Information Collection Views of Interactive Decision Making” *Organizational Behavior and Human Decision Processes,* Vol. 61, No. 3, 1995, pp 305-326
- Andreassen, P.” Judgmental extrapolation and market overreaction: On the use and disuse of news” *Journal of Behavioral Decision Making*, vol. 3 iss. 3, pp 153-174, Jul/Sep 1990
- Williams M. Dennis A., Stam A., Aronson J. “The impact of DSS use and information load on errors and decision quality” *European Journal of Operational Research,* Vol. 176, No. 1, 2007, pp 468-81
- Knutson et. al. “Nucleus accumbens activation mediates the influence of reward cues on financial risk taking” *NeuroRepor*t, 26 March 2008 - Volume 19 - Issue 5 - pp 509-513
- A small study presented at Cognitive Neuroscience Society meeting in 2009 by a grad student at U. of Michigan showed that simply being briefly exposed to smiling faces makes people more risk tolerant in betting games.
- Risk preferences show a strong correlation to testosterone levels – which change daily (Sapienza, Zingales, Maestripieri, 2009).
- Recalling past events that involved fear and anger change the perception of risk (Lerner, Keltner, 2001).