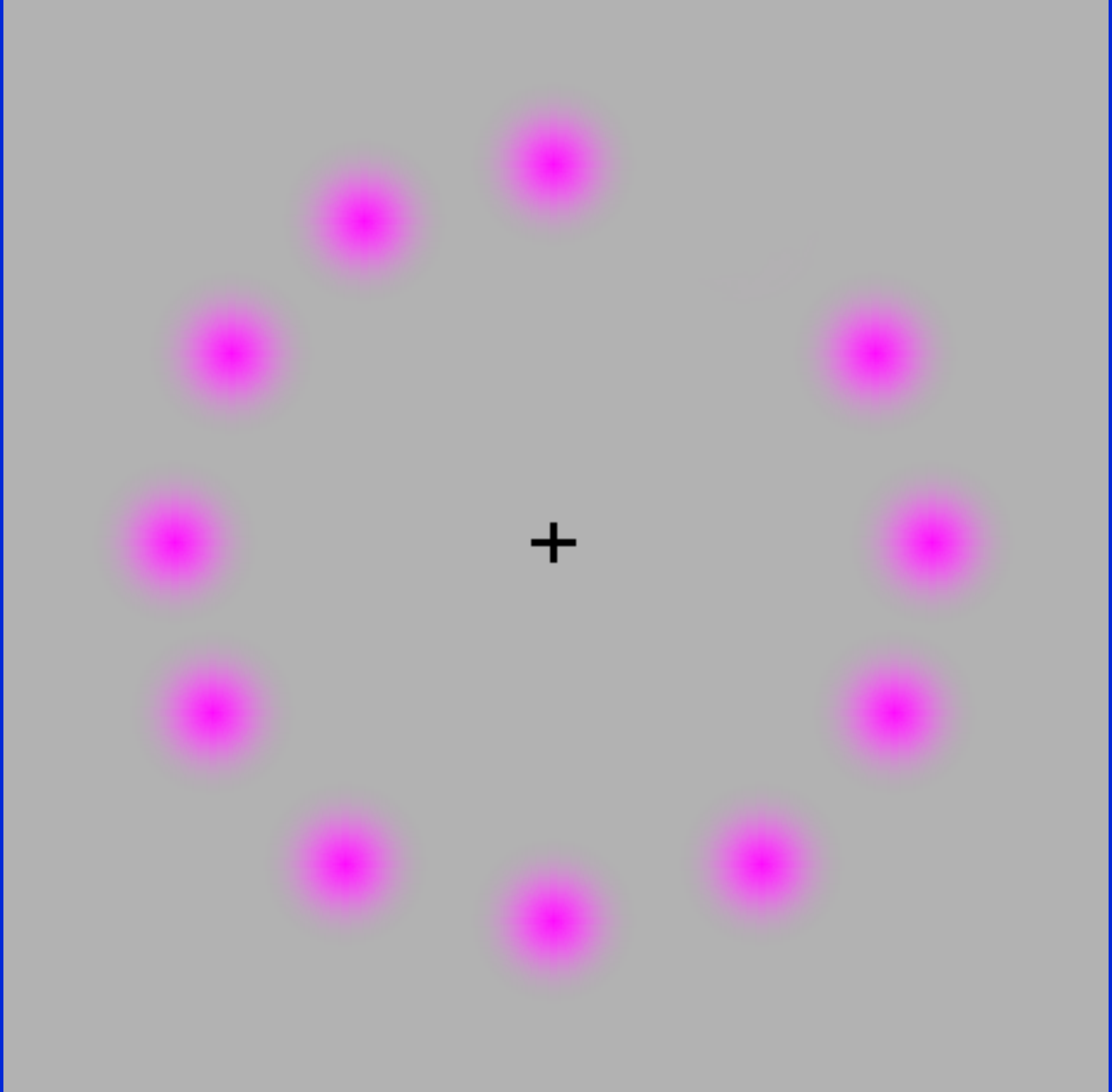
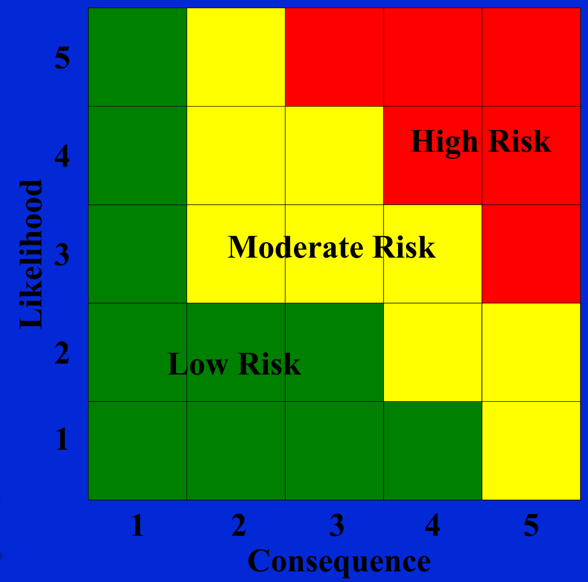
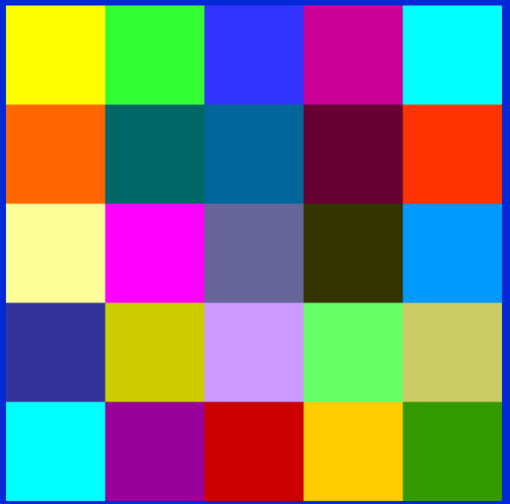
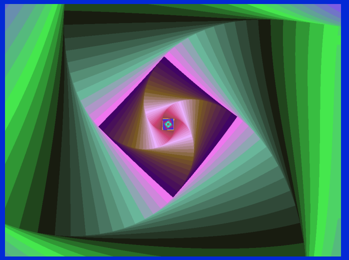


# Cognitive Biases in the Risk Matrix



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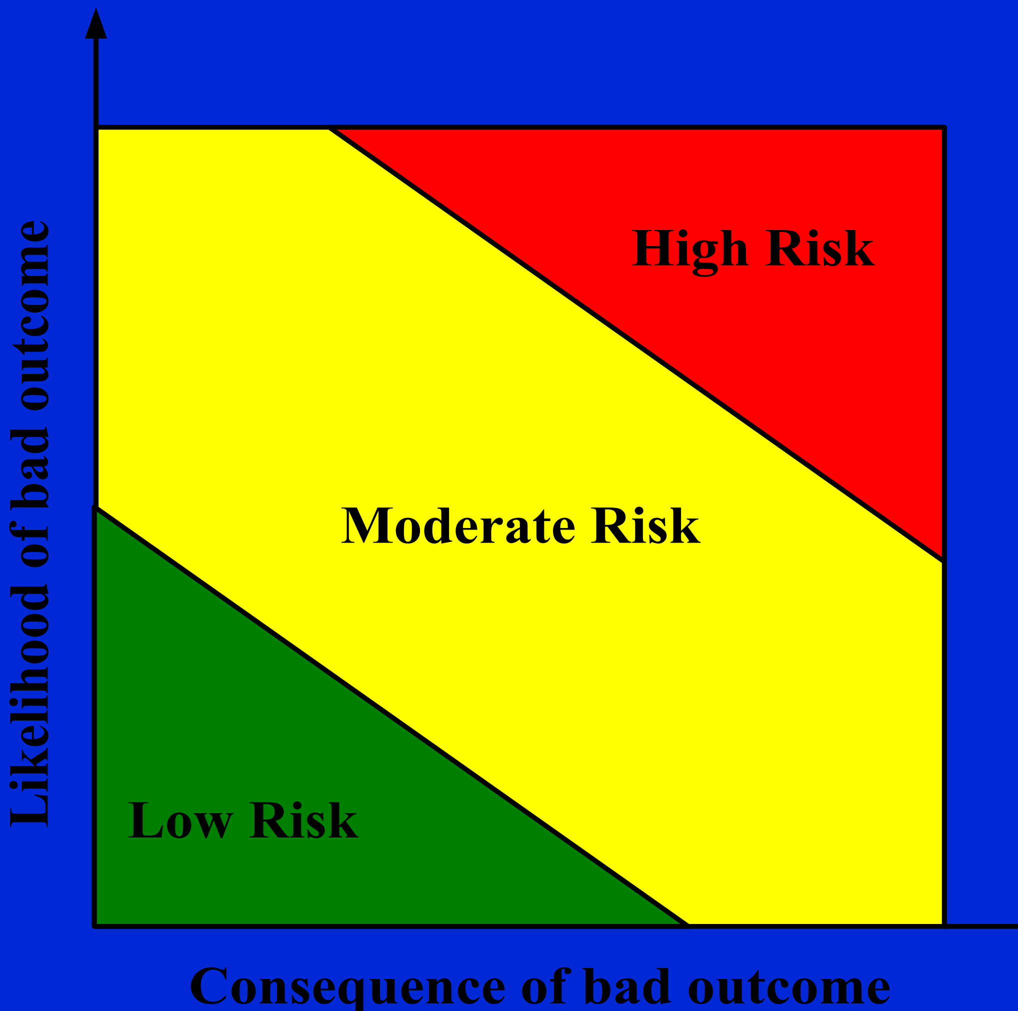
**“Fear of harm ought to be proportional not merely to the *gravity* of the harm, but also to the *probability* of the event.”**

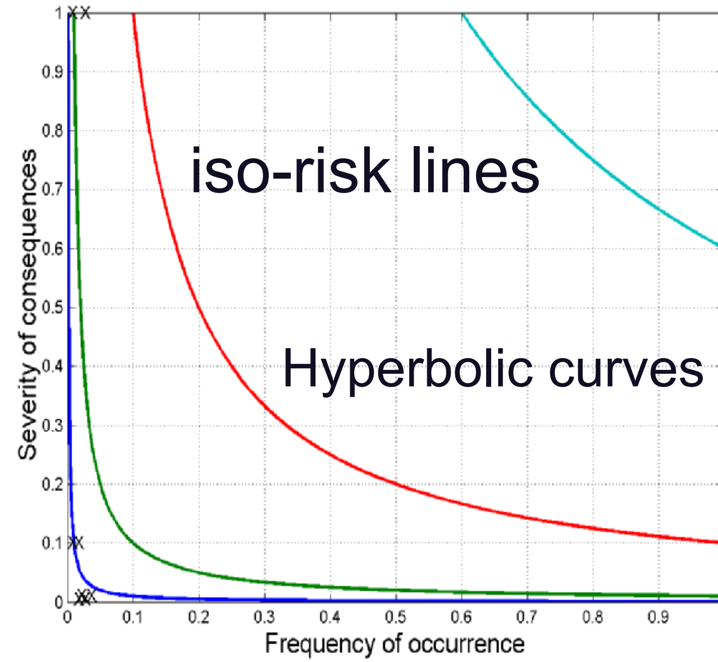
*Logic, or the Art of Thinking*

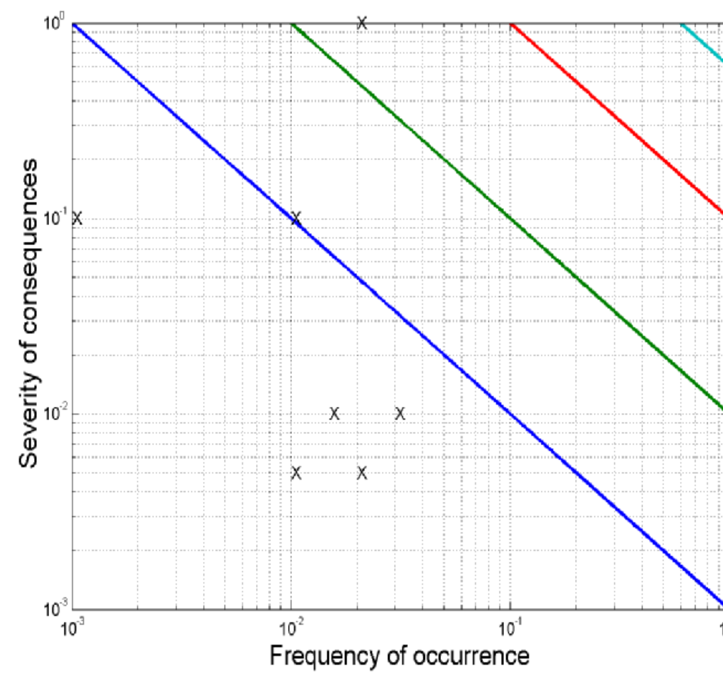
**Antoine Arnould, 1662**

**Consequence x Likelihood = Risk**

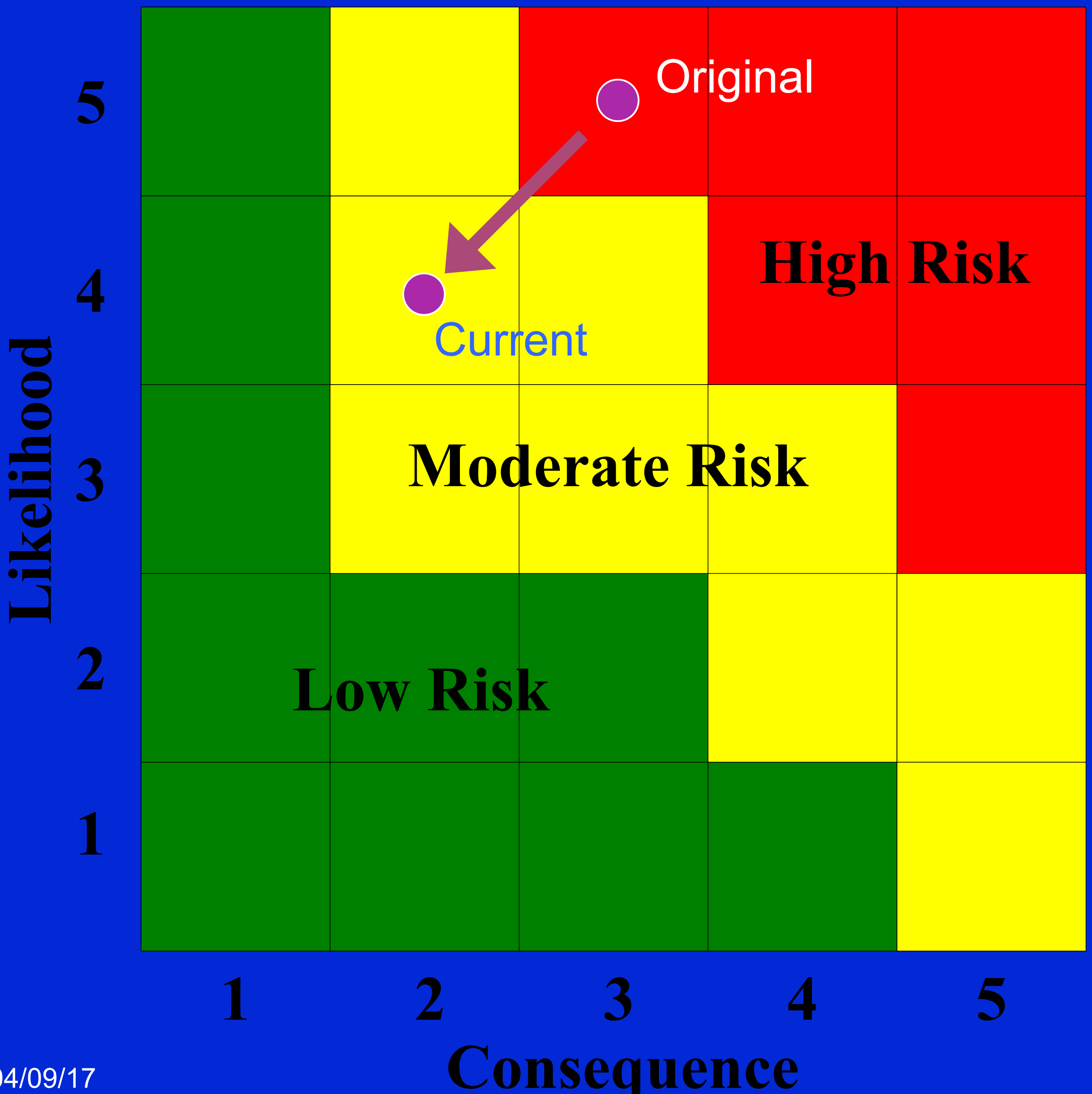
# Risk graphing



# 5 x 5 Risk "Cube"




Objective vs. Subjective data

"Campfire conversation" piece

# Present Situation

- Risk matrices are recognized by industry as the best way to:
  - consistently quantify risks, as part of a
  - repeatable and quantifiable risk management process
- Risk matrices involve human:
  - ❖Numerical judgment
    - ➢Calibration – location, gradation
    - ➢Rounding, Censoring
  - ❖Data updating
    - ➢often approached with under confidence
    - ➢often distrusted by decision makers

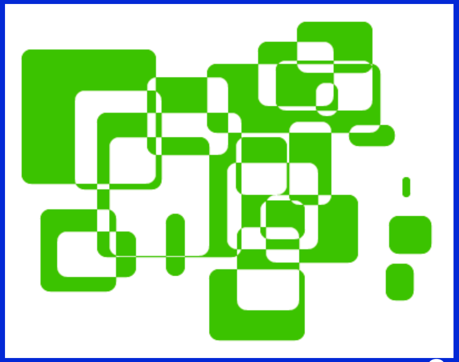
# Goal

- Risk Management improvement and better use of the risk matrix
  - Confidence in correct assessment of probability and value
  - Avoidance of specific mistakes
  - Recommended actions

# Heuristics and Biases

**Daniel Kahneman won the Nobel Prize in Economics in 2002 "for having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty.“**

**Similarities between cognitive bias experiments and the risk matrix axes show that risk matrices are susceptible to human biases.**



# Anchoring

- First impression dominates all further thought
- SS# Bias
- Questionnaire included last two digits of SS#
  - Answers to questions biased
    - High last two digits showed higher estimations
    - Lower last two digits showed lower estimations
- Obviating expert opinion
  - The analyst holds a circular belief that expert opinion or review is not necessary because no evidence for the need of expert opinion is present.

# Heuristics and Biases

**Presence of cognitive biases – even in extensive and vetted analyses – *can never be ruled out*.**

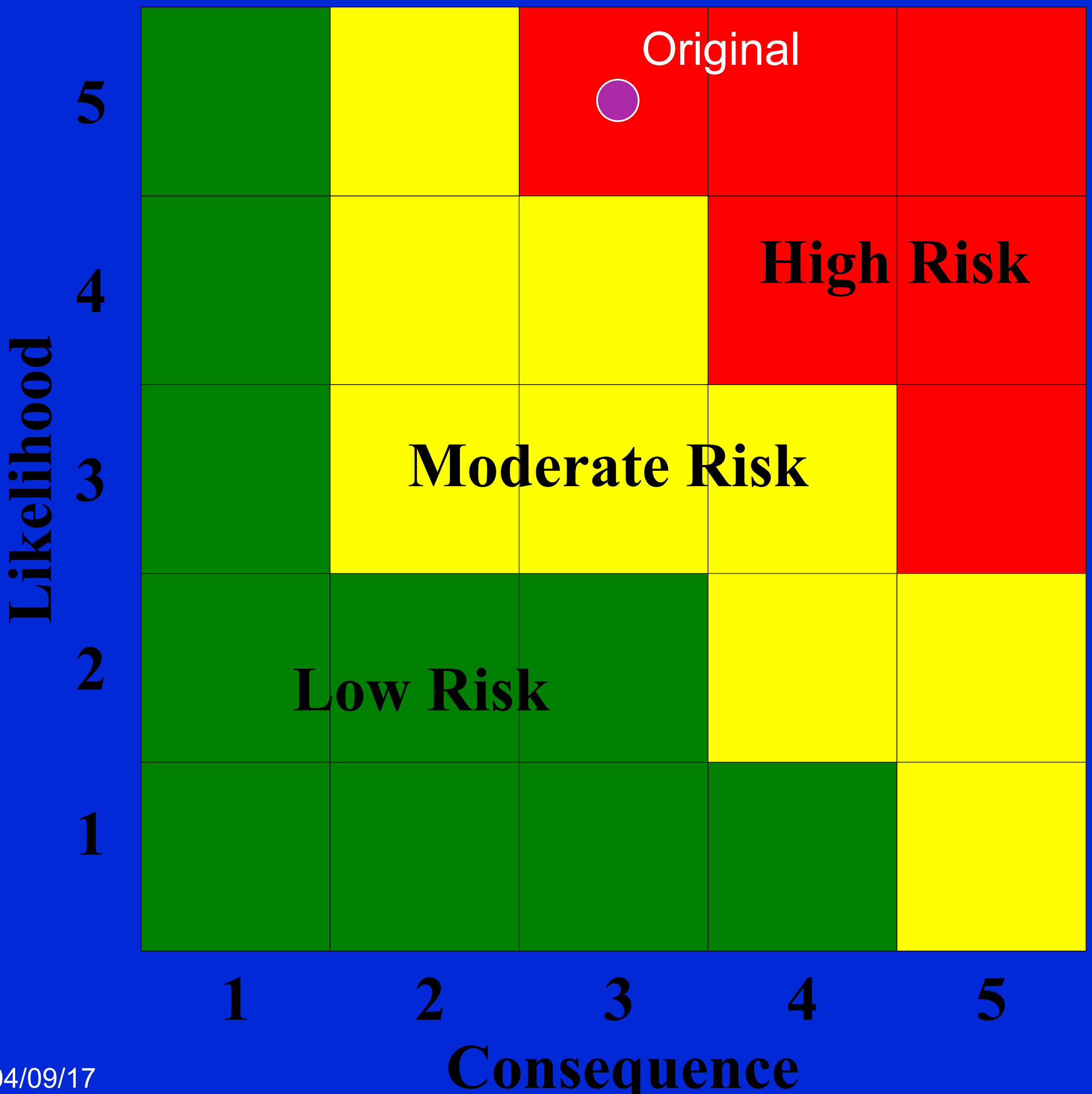
**Innate human biases, and exterior circumstances, such as the framing or context of a question, can *compromise* estimates, judgments and decisions.**

**It is important to note that subjects often maintain a *strong sense* that they are acting rationally while exhibiting biases.**

# Terminology

| **Subjective Parameters** | |
|---|---|
| ***Likelihood* (L)** | ***Consequence* (C)** |
| **Subjective Probability, $\pi(p)$** | **Utility (negative), $U^{-}(v)$** |
| | |
| **Y axis** | **X axis** |
| Objective Parameters | |
| Objective Probability, $p$ | Objective Value, $v$ |

# 5 x 5 Risk "Cube"




Objective vs. Subjective data

Communication Tool

# Likelihood

1. **Frequency of occurrence** is objective, discrete (coin toss)
2. **Probability** is continuous, fiction
   - "Humans judge probabilities poorly" [Cosmides and Tooby, 1996]
3. **Likelihood** is a subjective judgment (unless mathematical)

# Consequence, C

- Objective Consequence determination is costly
  - Total life-cycle cost increased by determination
- Mil-Std 882d

| | $ damage | Human impact | Environment | Law |
|---|---|---|---|---|
| Catastrophic | > $1M | Death, Disability | irreversible damage | Violate |
| Critical: | $1M - $200K | Hospitalization to >= 3 personnel | Reversible damage | Violate |
| Marginal: | $200K- $10K | Loss of work days; injury | Mitigation damage | |
| Negligible: | $10K-$2K | No lost work day; injury | Minimal damage | |

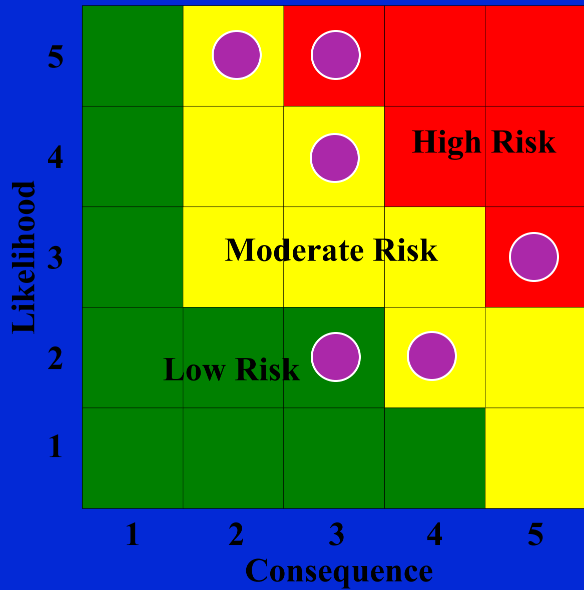
# Case Study

- Industry risk matrix data
  - 1412 original and current risk points (665)
    - Two programs used for raw data
    - Time of first entry known
    - Time of last update known
  - Cost, Schedule and Technical Impact known
  - Risk Subject not known
- Biases revealed
  - Likelihood and consequence judgment

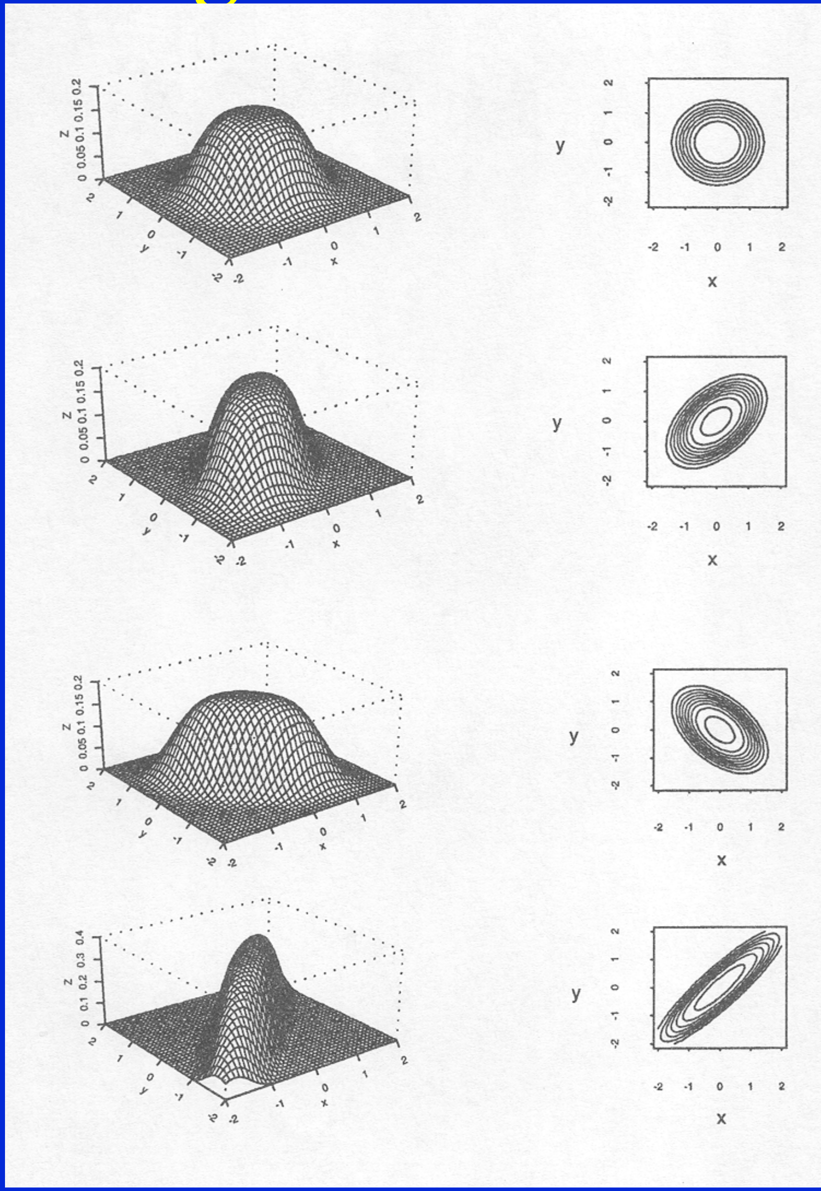
# Magnitude vs. Reliability [Griffin and Tversky, 1992]

- **Magnitude perceived more valid**
  - **Data with outstanding magnitudes but poor reliability selected and used**
- **Suggestion:**
  - **Data with uniform source reliability**
    - **Speciousness of data**
- **<u>Observation</u>: Risk Matrices are magnitude driven, without regard to reliability**

# Expected Distribution for original risk points in Risk Matrix?




Uniform:



Bivariate Normal

# 1. Estimation in a Pre-Define Scale Bias

- **Response scale effects judgment [Schwarz, 1990]**
- **Two questions, random 50% of subjects:**

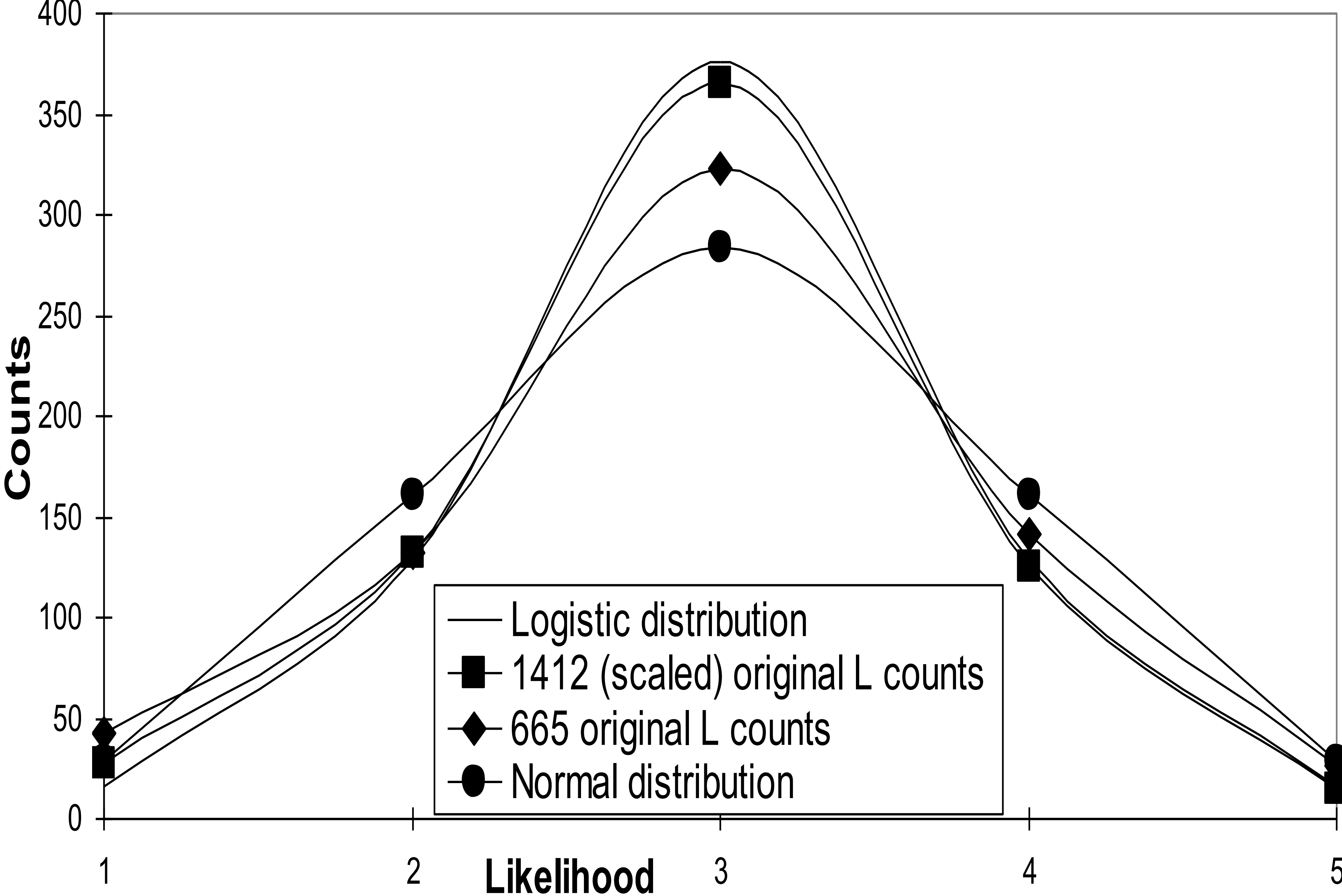
- **Please estimate the average number of hours you watch television per week:**

| _____ | _____ | __X__ | _____ | _____ | _____ |
|---|---|---|---|---|---|
| **1-4** | **5-8** | **9-12** | **13-16** | **17-20** | **More** |

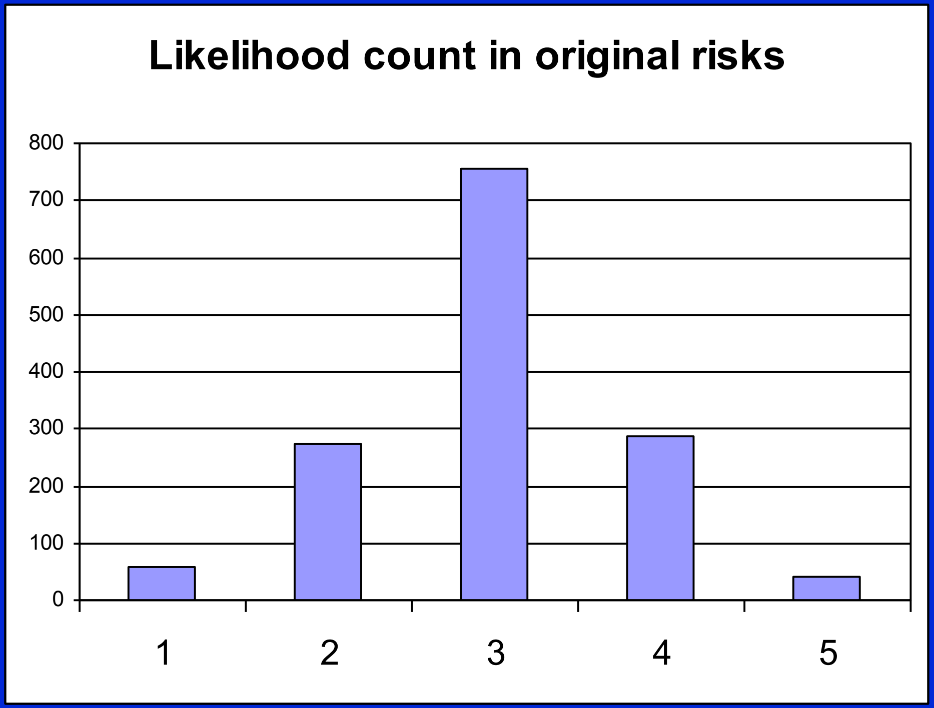
- **Please estimate the average number of hours you watch television per week:**

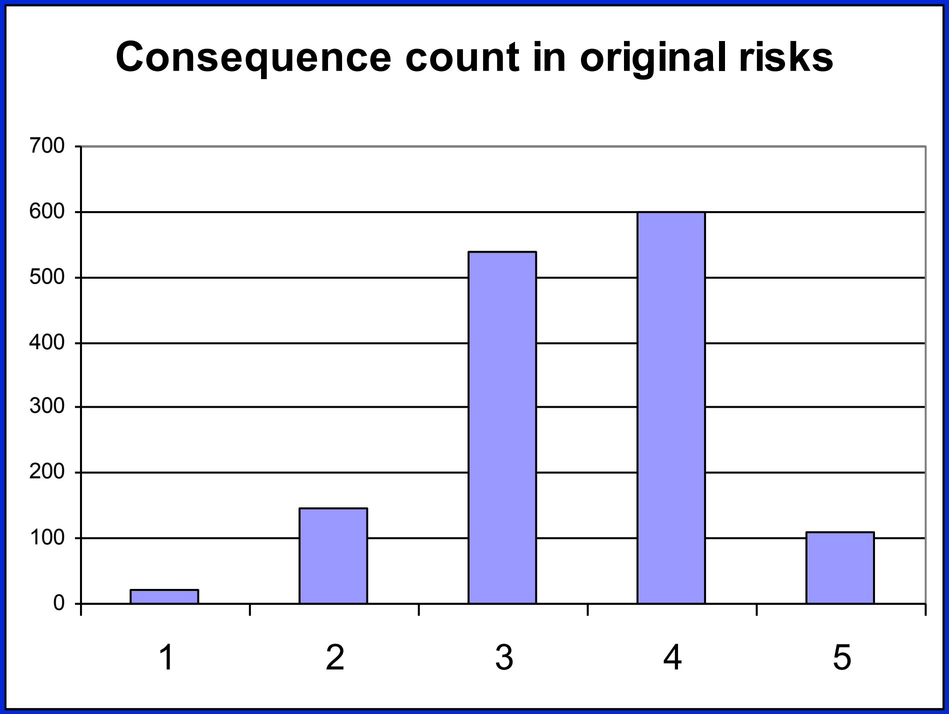
| _____ | _____ | __X__ | _____ | _____ | _____ |
|---|---|---|---|---|---|
| **1-2** | **3-4** | **5-6** | **7-8** | **9-10** | **More** |

# Likelihood: Logistic, 1412, 665, and Normal



# Effect of Estimation in a Pre-Defined Scale



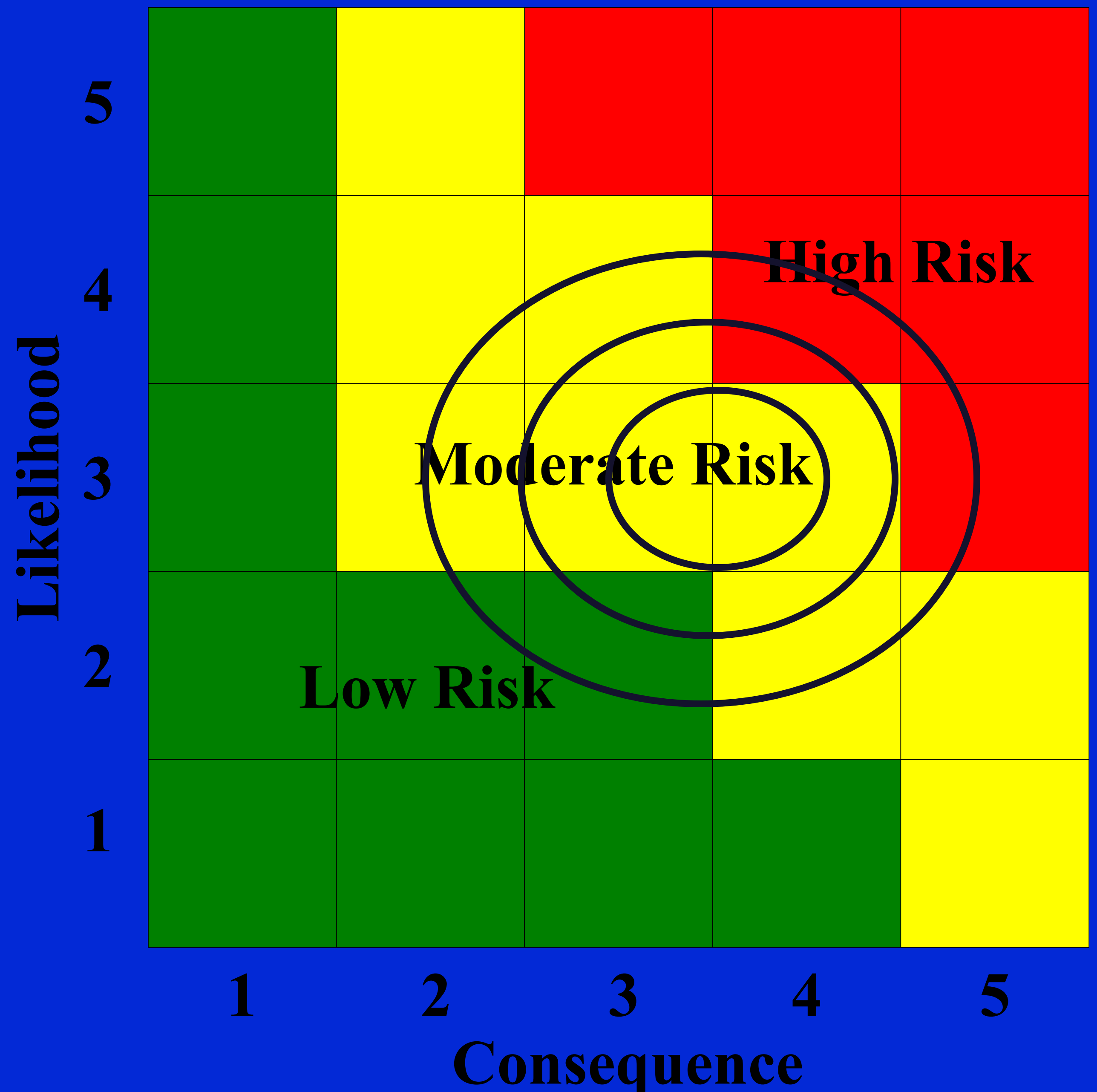

'People estimate probabilities poorly'
[Cosmides and Tooby, 1996]

Consequence/Severity amplifiers

# Consequence Amplifiers

- Lack of control
- Lack of choice
- Lack of trust
- Lack of warning
- Lack of understanding
- Manmade
- Newness
- Dreadfulness
- Personalization
- Recallability
- Eminency

# 5 x 5 Risk Matrix



# Situation assessment

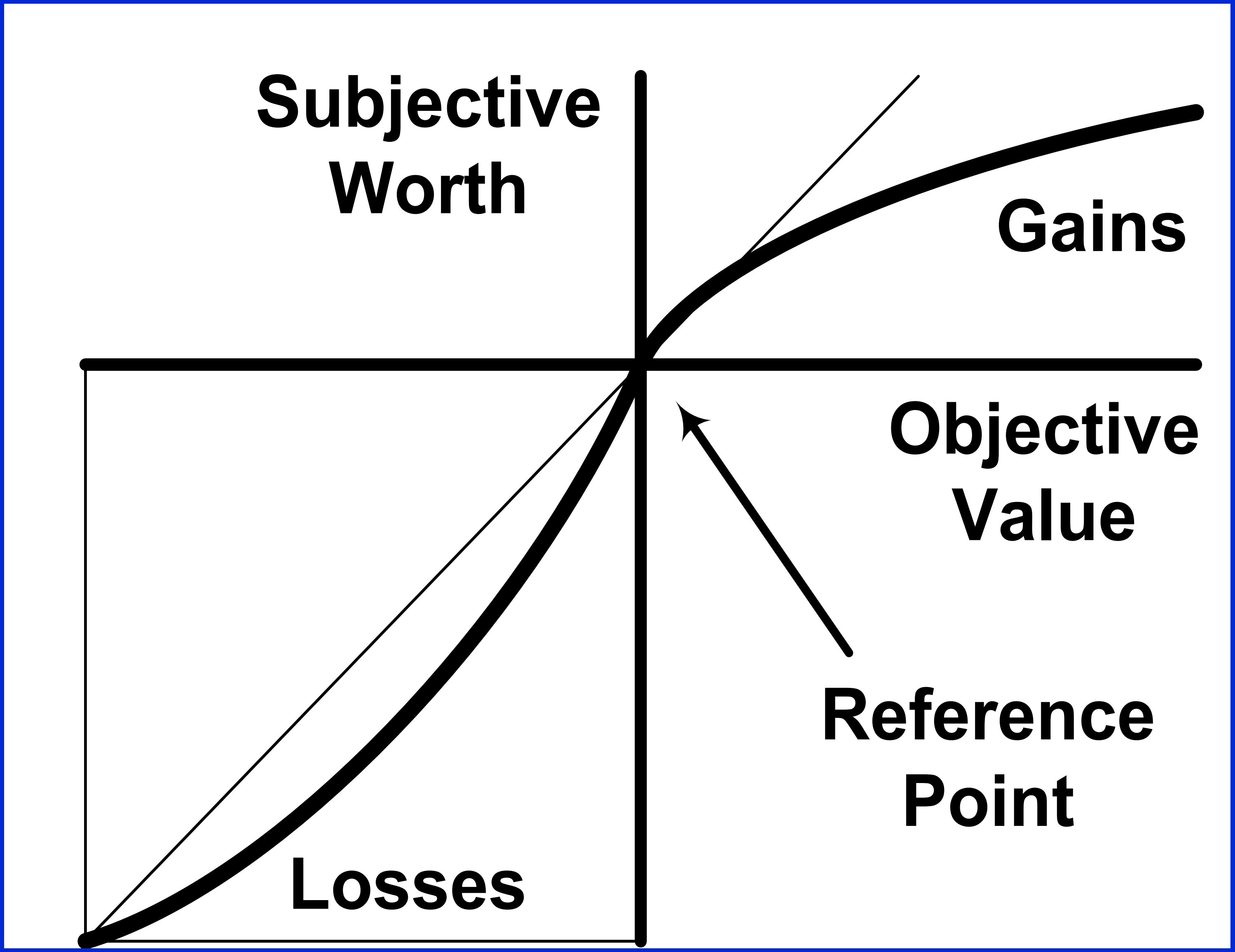
- 5 x 5 Risk Matrices seek to increase risk estimation consistency

- Hypothesis: Cognitive Bias information can help improve the validity and sensitivity of risk matrix analysis

# Prospect Theory

- Decision-making described with subjective assessment of:
  - Probabilities
  - Values
- Prospect Theory:
  - Probabilities and values are subjectively assessed

# Gains and losses are not equal*



# *Subjective Utility*

- **Values considered from reference point established by the subject's wealth and perspective**
  - **Framing**
- **Gains and losses are subjectively valued**
  - **1-to-2 ratio.**
- **For gains:**

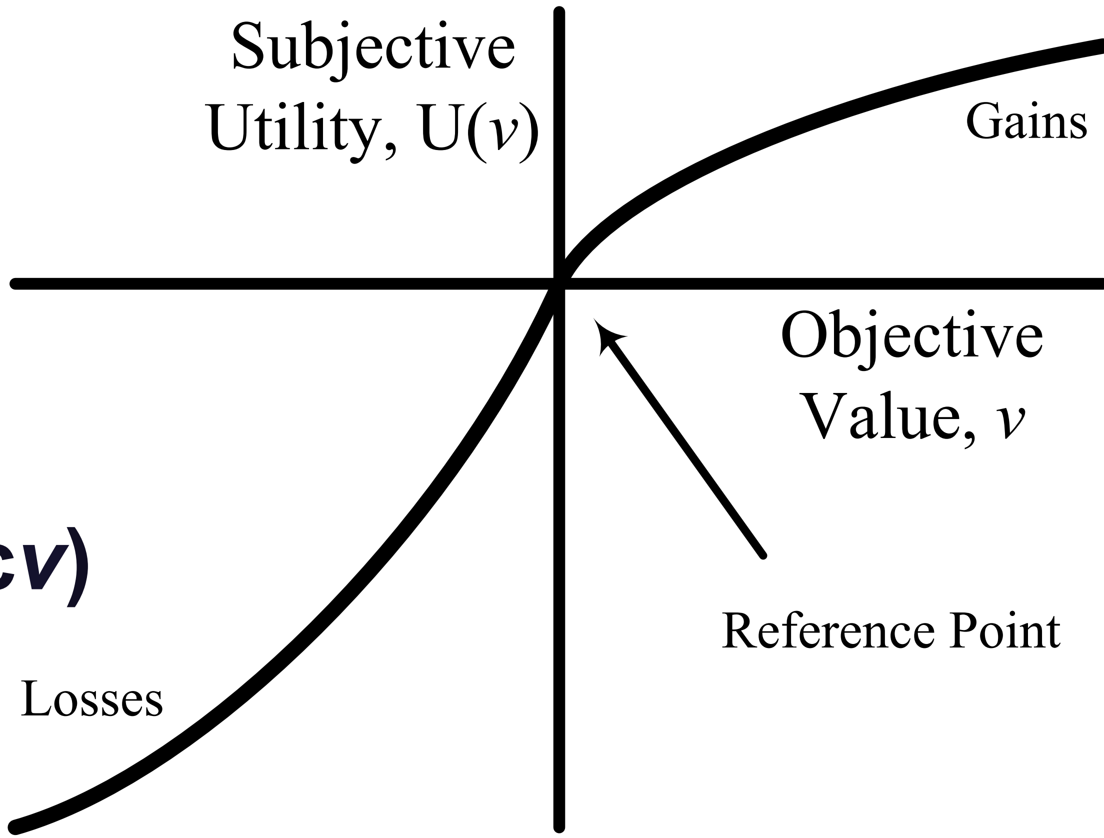
  $U^{+}(v) = Ln(1 + v)$
- **For losses:**

$$U^{-}(v) = -(\mu)Ln(1 - cv)$$

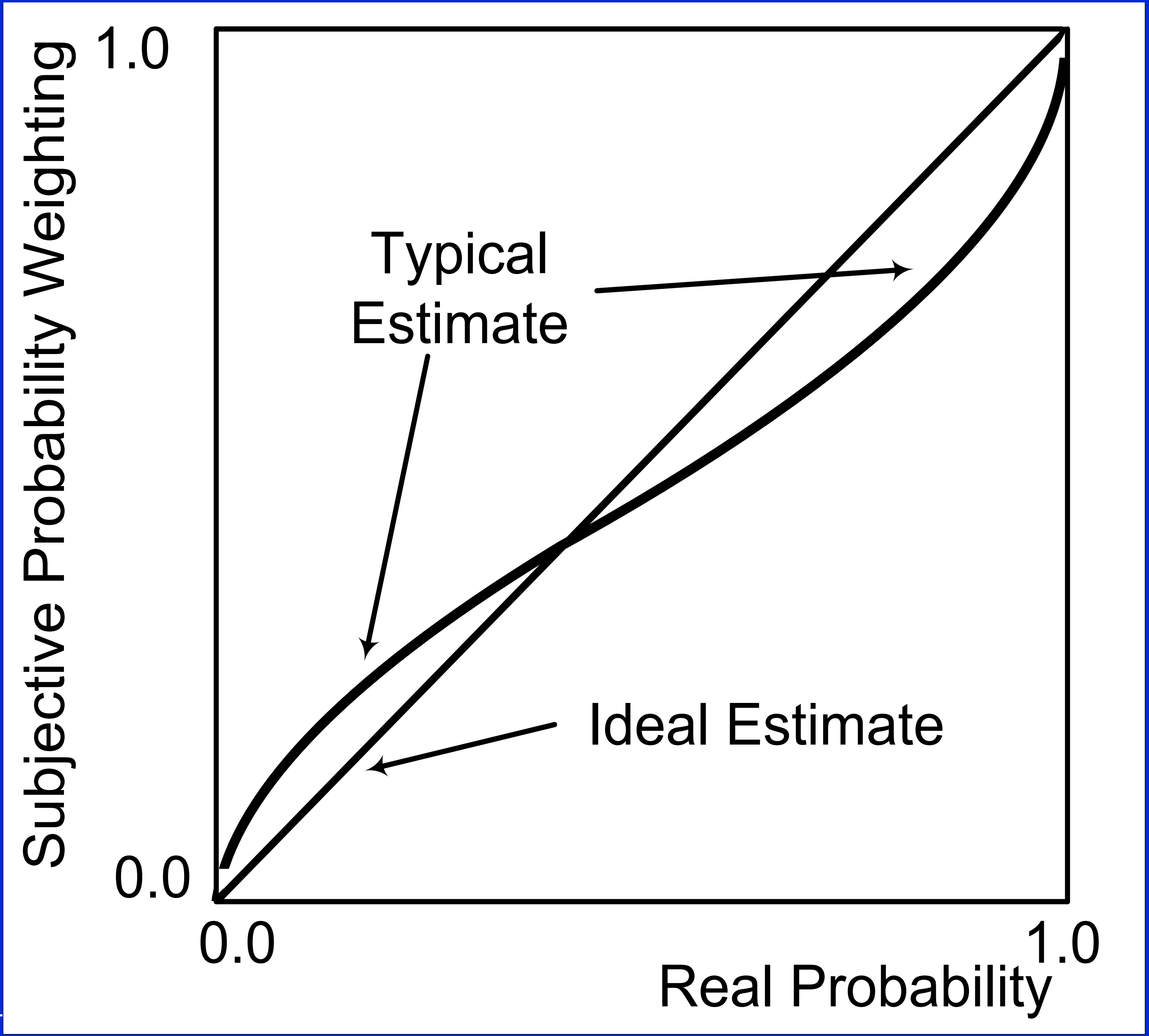
$\mu = 2.5$

c = constant

$v$ = objective value

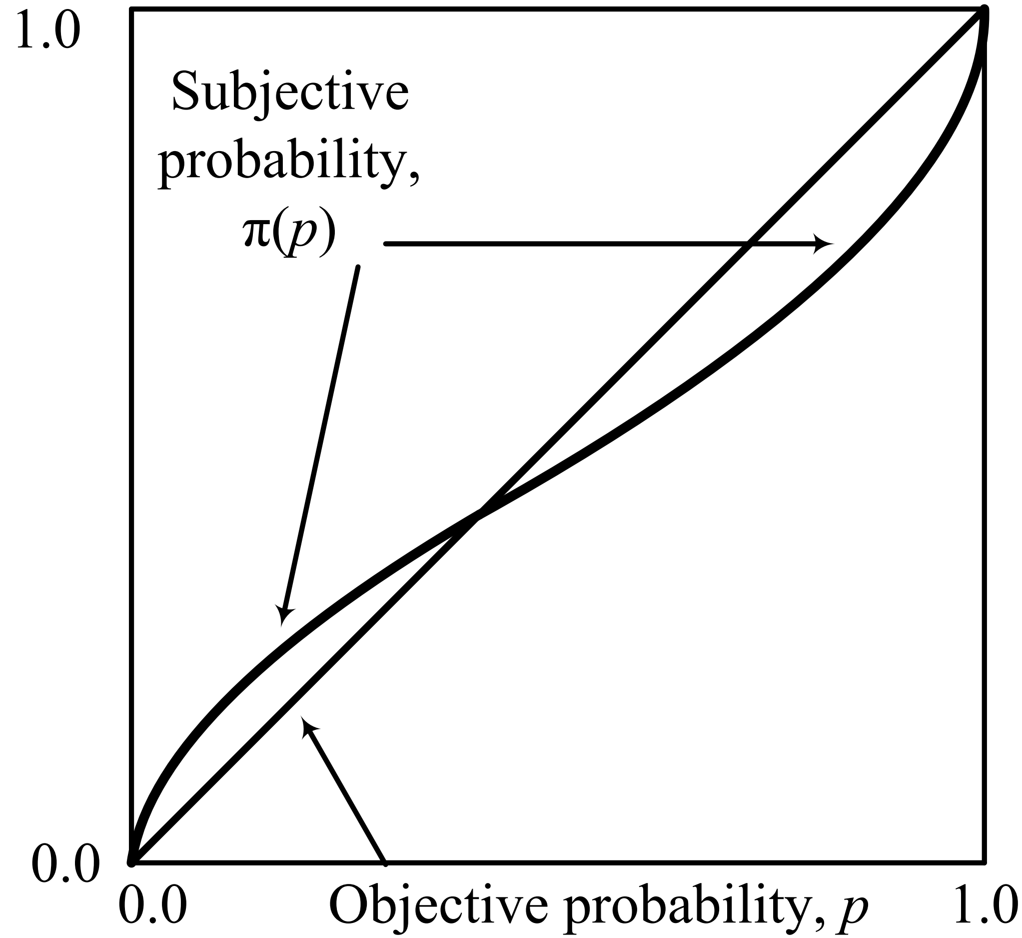


# Humans judge probabilities poorly*



# *Subjective Probability, π(p)*

- **small probabilities overestimated**
- **large probabilities underestimated**




**$\pi(p) =$**

**$(p^{\delta}) / [p^{\delta} + (1- p)\delta]^{(1/\delta)}$**

**$p$ = objective prob.**

**$0 < \delta \leq 1$**

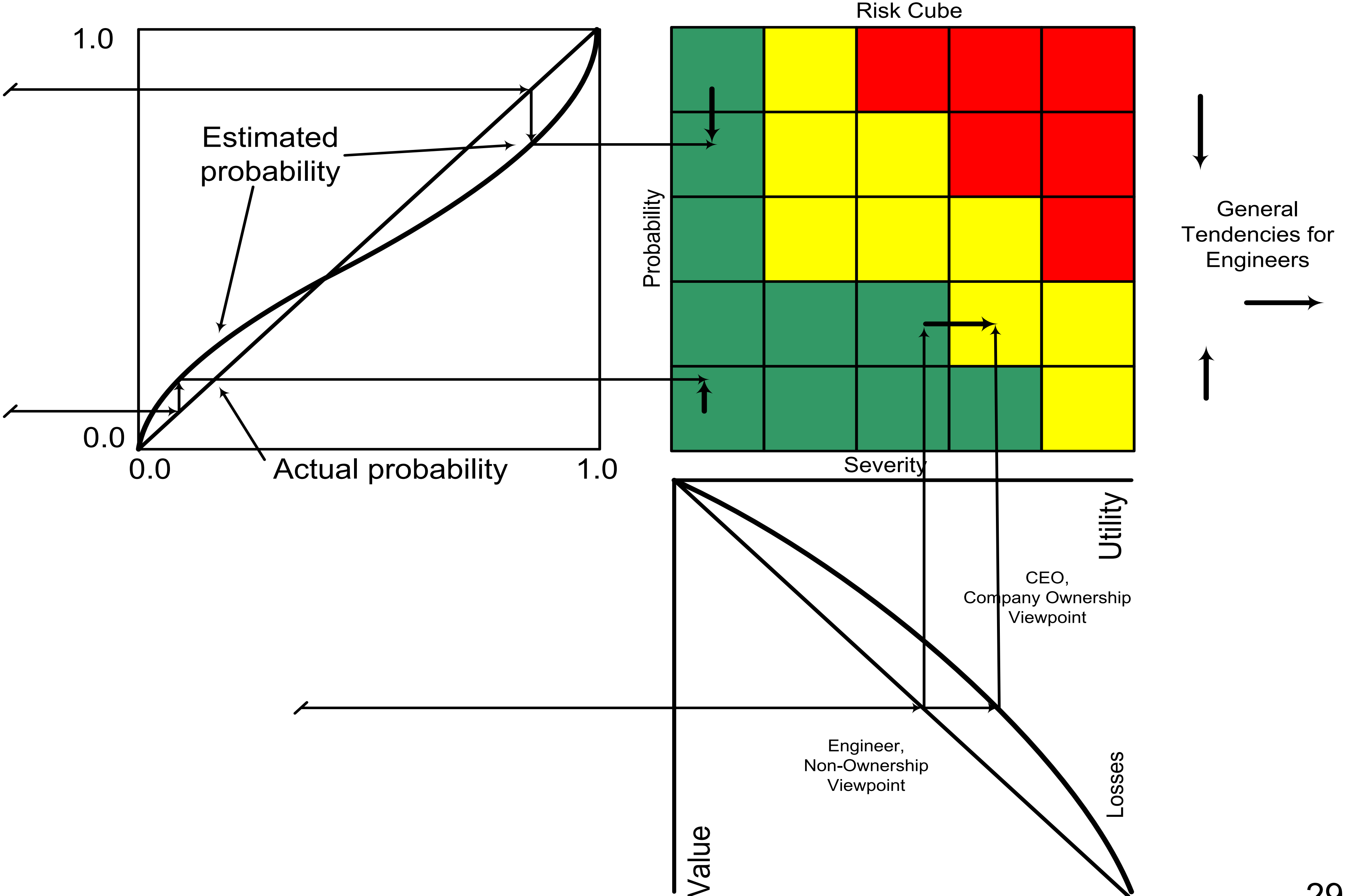
**usual value for $\delta$:**

**$\delta$ = 0.69 for losses**

**$\delta$ = 0.61 for gains**

**When $\delta$ =1, $\pi(p) = p$ = objective probability**

# *Implication of Prospect Theory for the Risk Matrix*



# ANALYSES AND OBSERVATIONS OF INITIAL DATA

**Impediments for the appearance of cognitive biases in the industry data:**

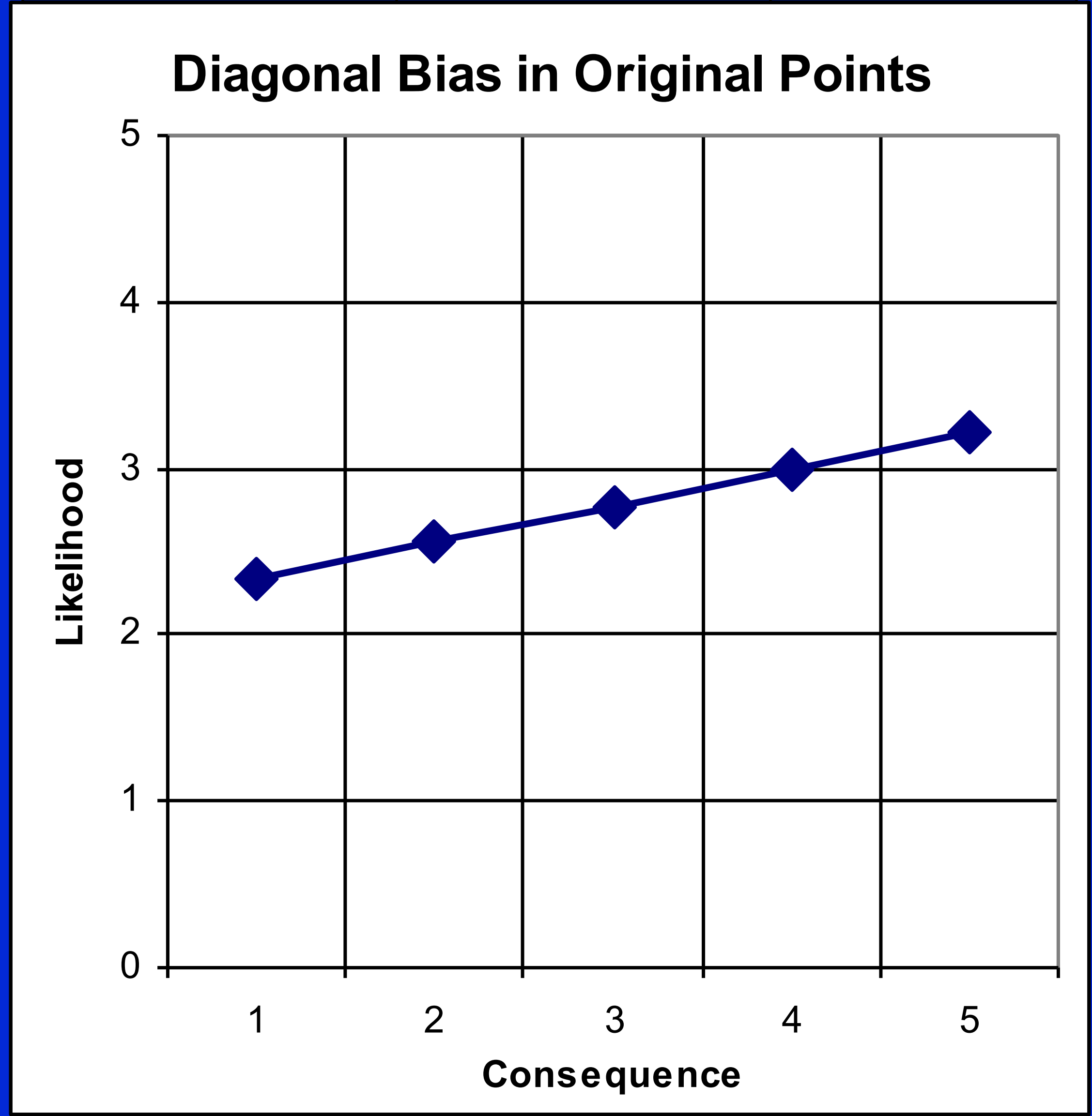
1) Our data are somewhat granular while the predictions of Prospect Theory are for continuous data
2) Qualitative descriptions of 5 ranges of likelihood and consequence
   - non-linear influence in the placement of risk datum points

**Nevertheless, the evidence of cognitive biases emerges from the data**

# 2. Diagonal Bias

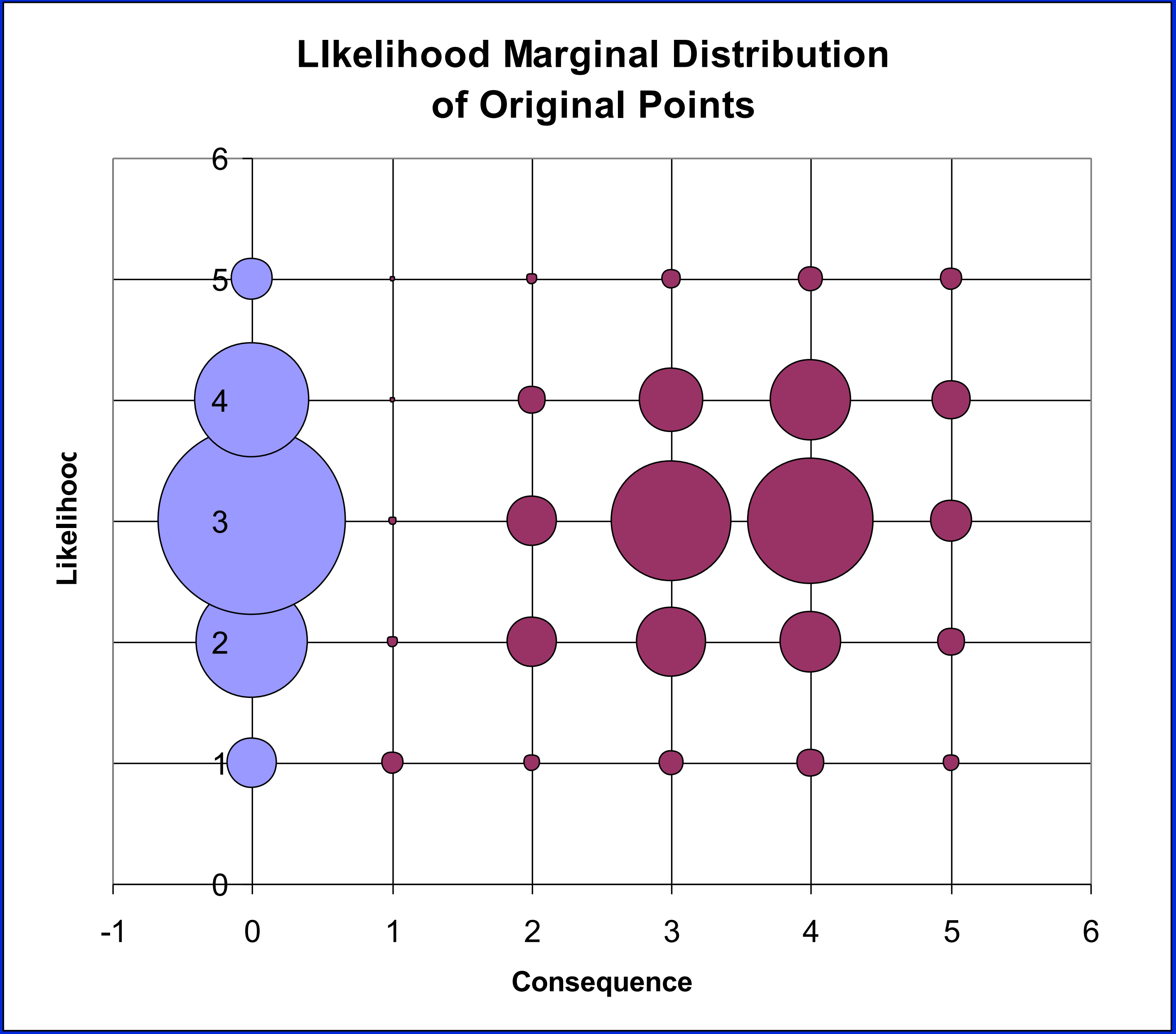
- **Anticipation of later moving of risk points toward the origin**
- **Risk points withdrawn from the origin upward and rightward along the diagonal**

| Regression on 1412 Original Points | | |
|---|---|---|
| Intercept | Slope | R |
| 2.2 | 0.22 | 0.22 |



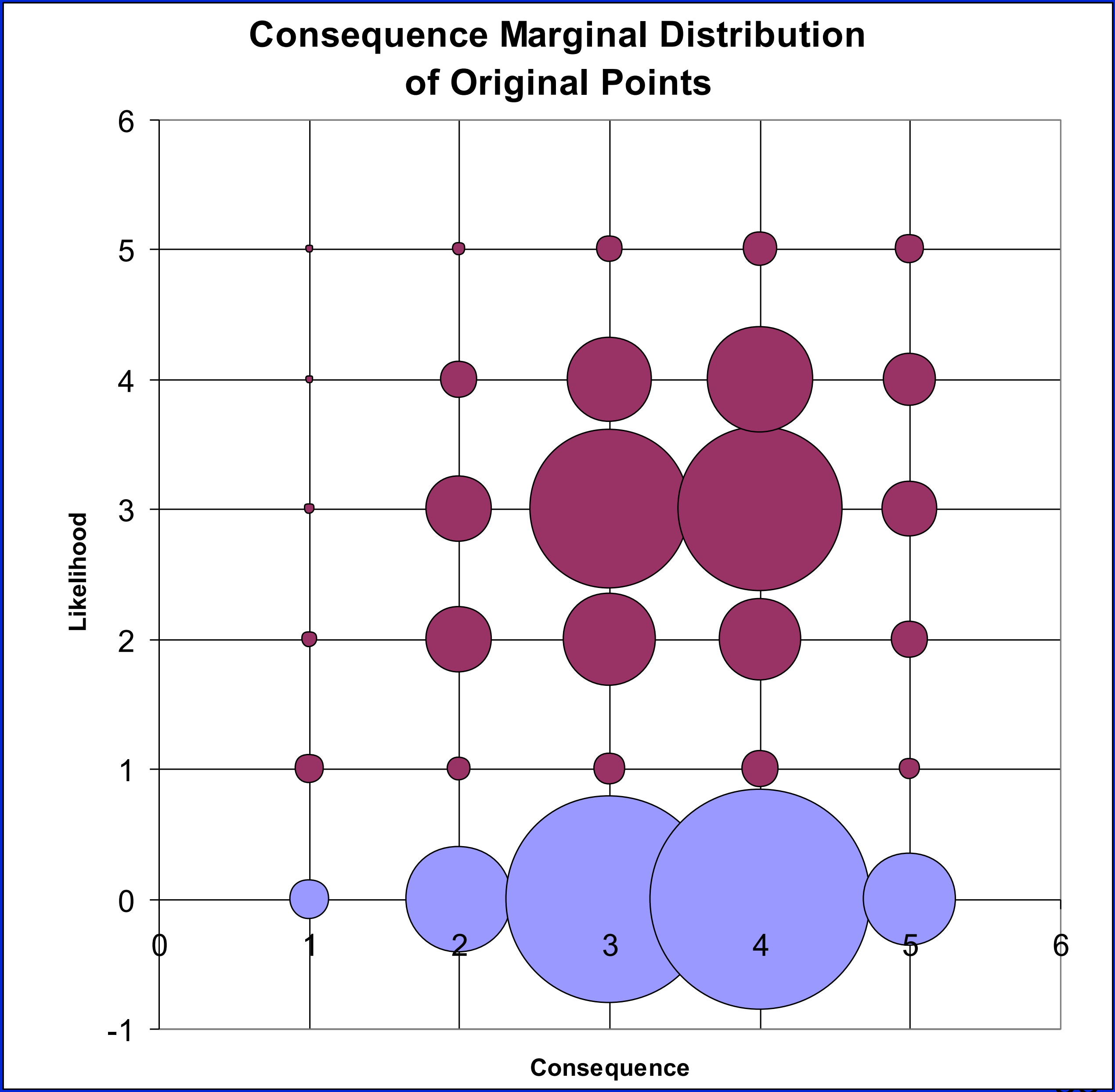
# 3. Probability Centering Bias

- **Likelihoods are pushed toward**
  **L = 3**
- **Symmetric to a first order**

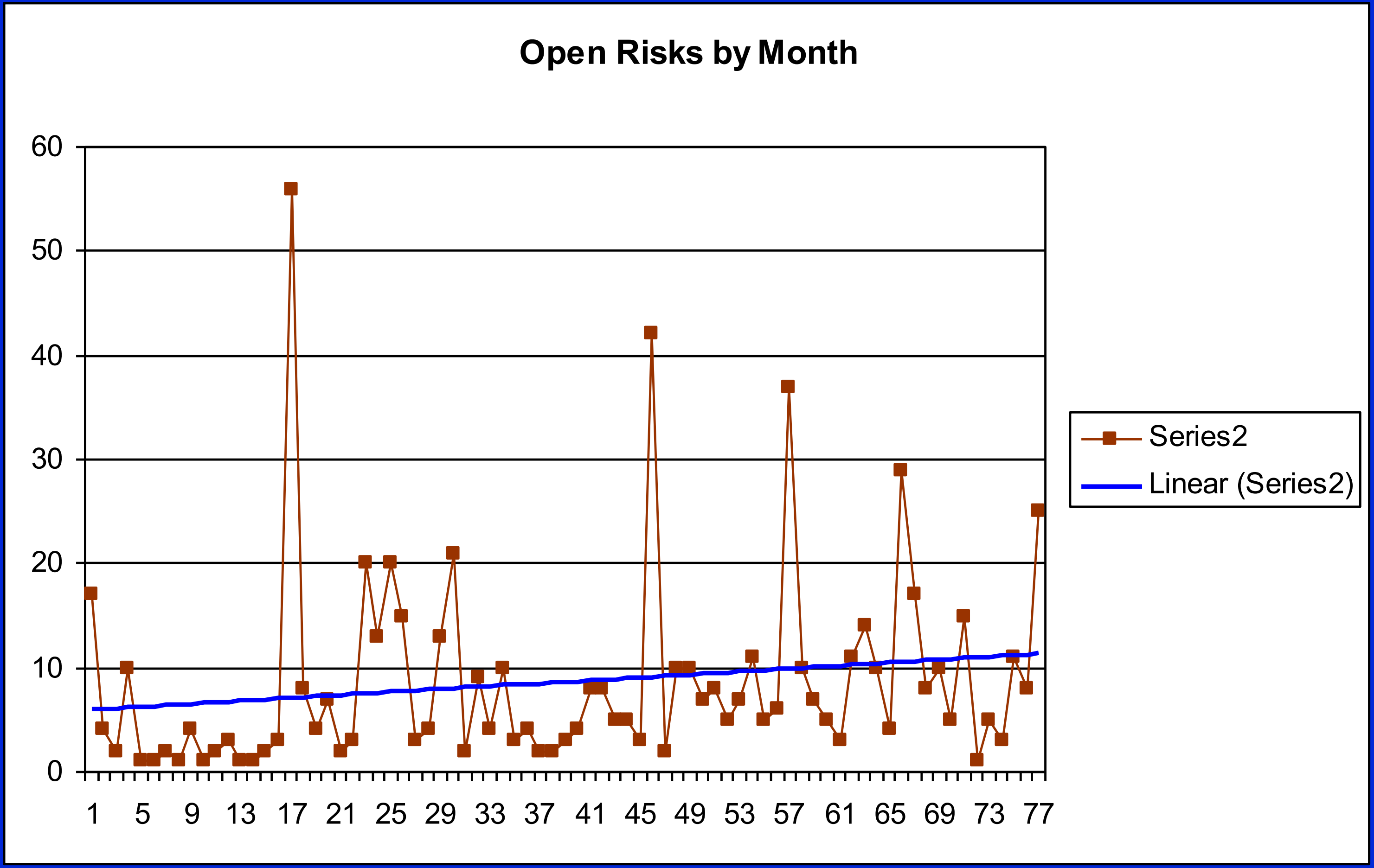


# 4. Consequence Bias

- **Consequence is pushed higher**
- **Engineer identifies with increased risk to entire corporation**
- **'Personal' corporate risk**



Units




Time (Months)

# Likelihood mitigation recommendations

- **Engineers and Management**
  1. **Technical risk highest priority**
  2. **Schedule risk communicated well by management**
  3. **Cost risk likelihood less frequently communicated by management.**

- ➢ **Higher cognizance of cost risk will be valuable at the engineering level**

| Likelihood mitigation |
| --- |
| 1. Technical |
| 2. Schedule |
| 3. Cost |

# Consequence Mitigation

- Engineers:
  1. Schedule consequences effect careers
  2. Technical consequences effect job performance reviews
  3. Cost consequences are remote and associated with management

| Consequence mitigation |
| --- |
| 1. Schedule |
| 2. Technical |
| 3. Cost |

- Higher cognizance of cost risk would be valuable at the engineering level

# CONCLUSION

- First time that the effects of cognitive biases have been documented within the risk matrix
- Clear evidence that probability and value translations, as likelihood and consequence judgments, are present in industry risk matrix data
- Steps
  - 1) the translations were predicted by prospect theory, 2) historical data confirmed predictions

- Risk matrices are not objective number grids
- Subjective, albeit useful, means to verify that risk items have received risk-mitigating attention.

# Suggestions for risk management improvement

- Objective basis of risk:
  - Frequency data for Probability
  - $ for Consequence
- Long-term, institutional rationality
- Team approach
- Iterations
- Expert review
- Biases and errors awareness

# SUCCESS

OPPORTUNITY

# RISK

## IDE / SYS ENG 427-FUNCTION BASED RISK ANALYSIS

Risk is a necessary ingredient for SUCCESS! Effective identification and management of risk and opportunity is a must for the advancement of technology. IDE/Sys Eng 427 presents the risk tools engineers need to thrive in today's ever changing technological environment.

**Course Topics**

This exciting interdisciplinary engineering course will cover advanced engineering techniques in Probabilistic Risk Analysis (PRA)such as Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis, Event Tree Analysis, etc. will be covered in the context of a range of interdisciplinary products. New state-of-the-art autonomous PRA techniques and risk mitigation plans will also be covered with emphasis placed on early risk identification. These topics will be investigated and implemented over a wide range of products including space shuttles, nuclear power plants, automobiles, computer systems, and house hold products.

**IDE/Sys Eng 427-Function Based Risk Assessment**

*Fall 2008*
*For more information:*
*Dr. Katie Grantham Lough*
*kag@mst.edu*

# References


- L. Cosmides, and J. Tooby, Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty, Cognition 58 (1996), 1-73.
- D. Kahneman, and A. Tversky, Prospect theory: An analysis of decision under risk, Econometrica 46(2) (1979), 171-185.
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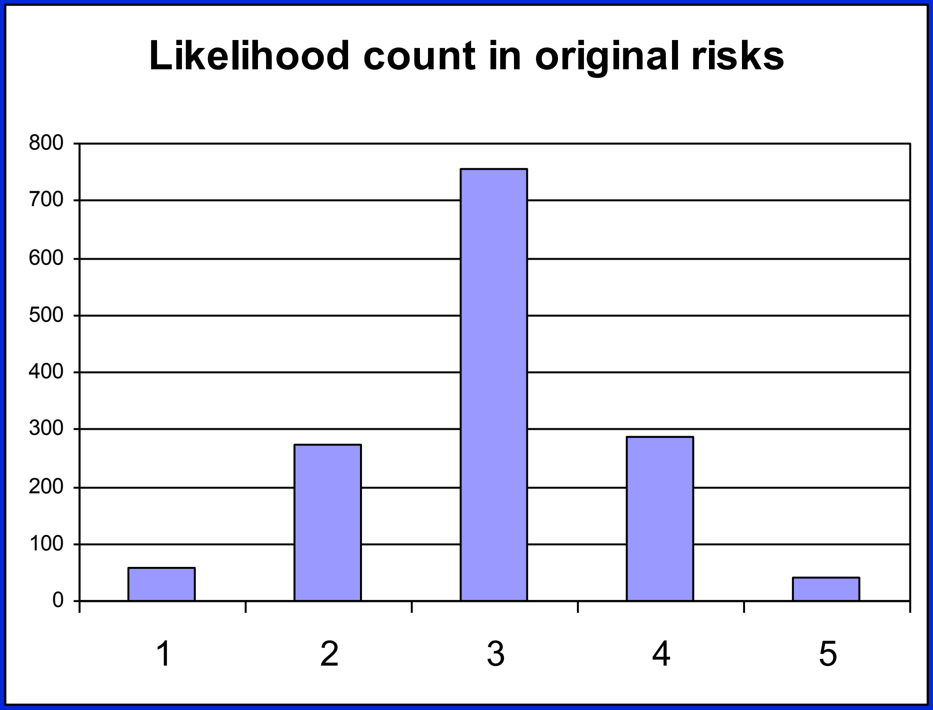
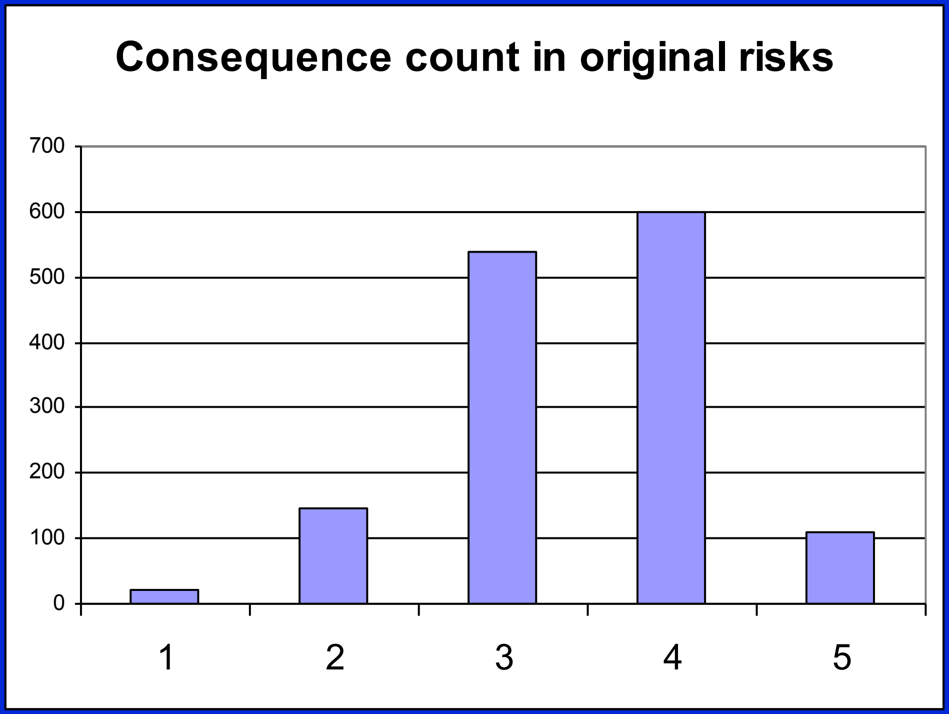
- N. Schwarz, Assessing frequency reports of mundane behaviors: Contributions of cognitive psychology to questionaire construction, Review of Personality and Social Psychology 11 (1990), 98-119.
- A. Tversky, and D. Kahneman, Advances in prospect theory: Cumulative representation of uncertainty, Journal of Risk and Uncertainty 5 (1992), 297-323.

- **Comments !**
- **Questions ?**

- **Back up**

# Effect of Estimation in a Pre-Defined Scale

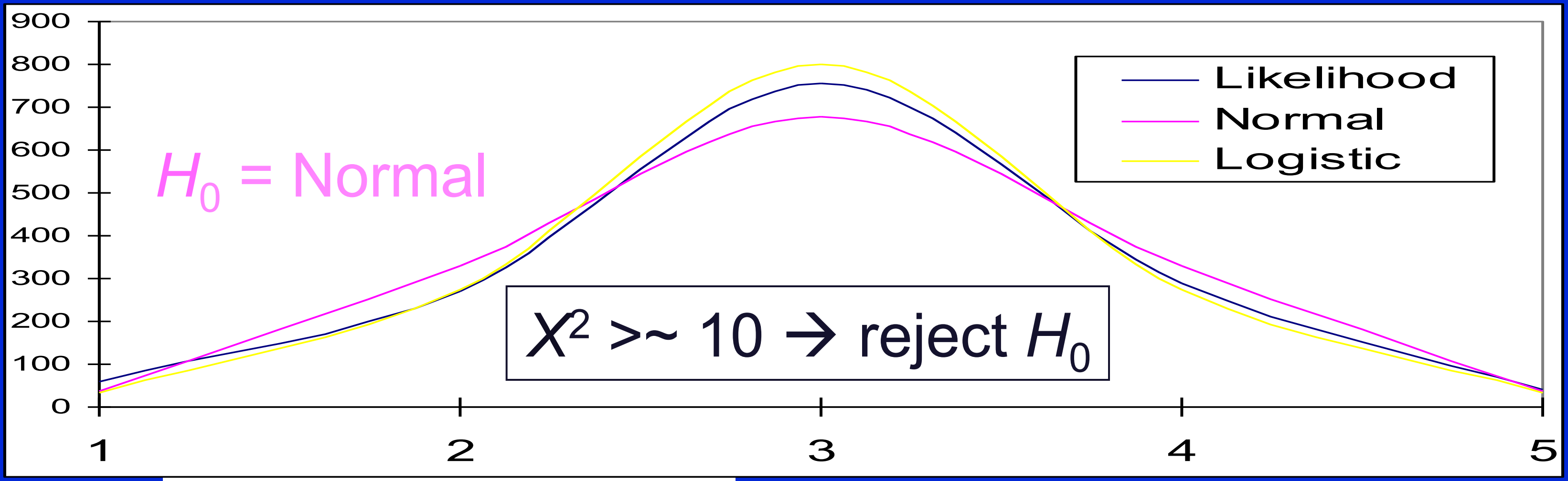



'People estimate probabilities poorly' [Cosmides and Tooby, 1996]

Consequence/Severity amplifiers

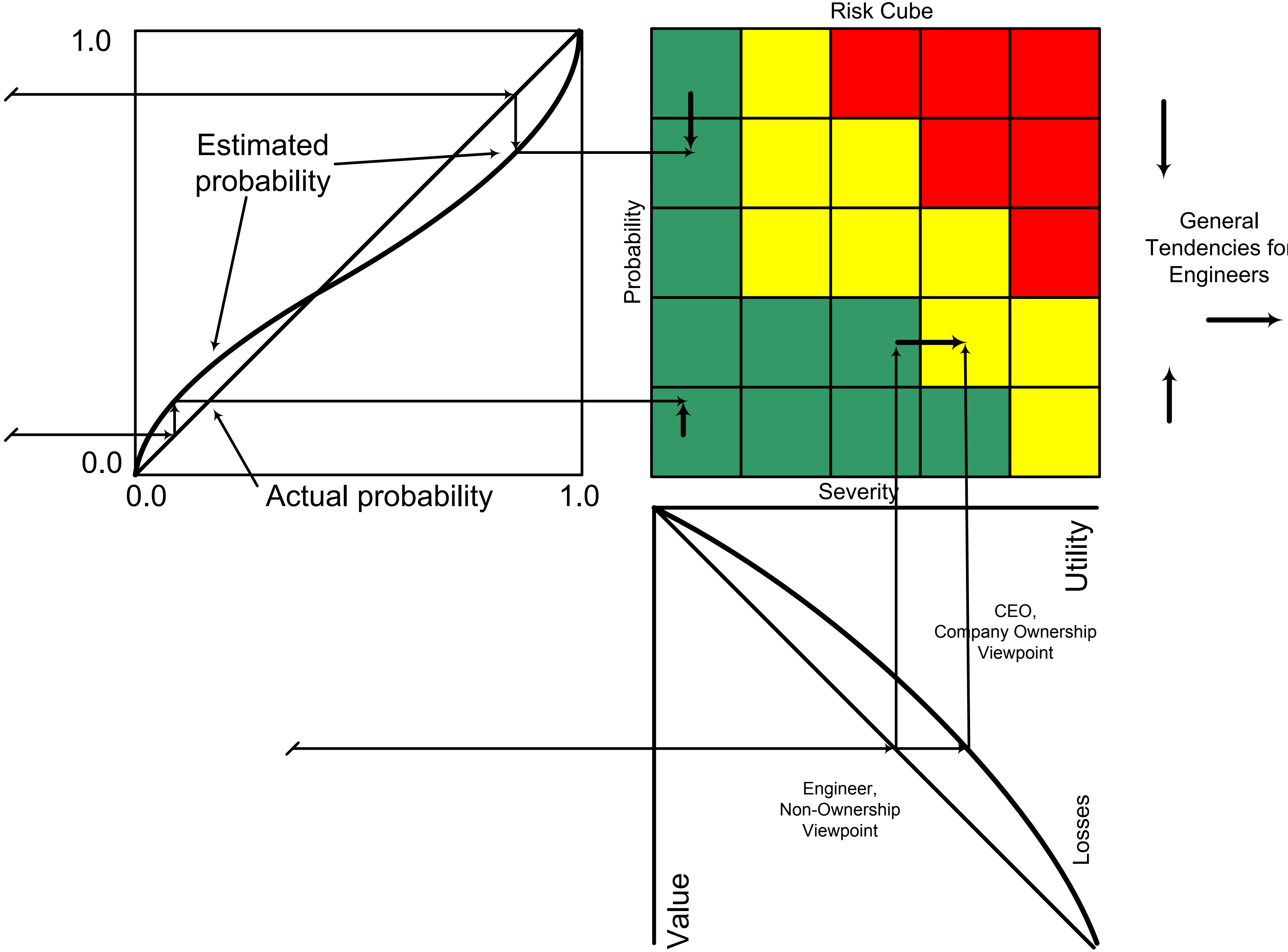
| Likelihood Marginal Distribution of Original Points | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 58 | 272 | 754 | 288 | 40 |
| Normal distribution with $\mu = 3.0$, $\sigma = 0.78$ | | | | |
| 38 | 330 | 676 | 330 | 38 |
| $\Delta$ = actual – normal | | | | |
| 20 | - 58 | 78 | - 42 | 2 |




$$\chi_N^2 = 36, df = 4$$

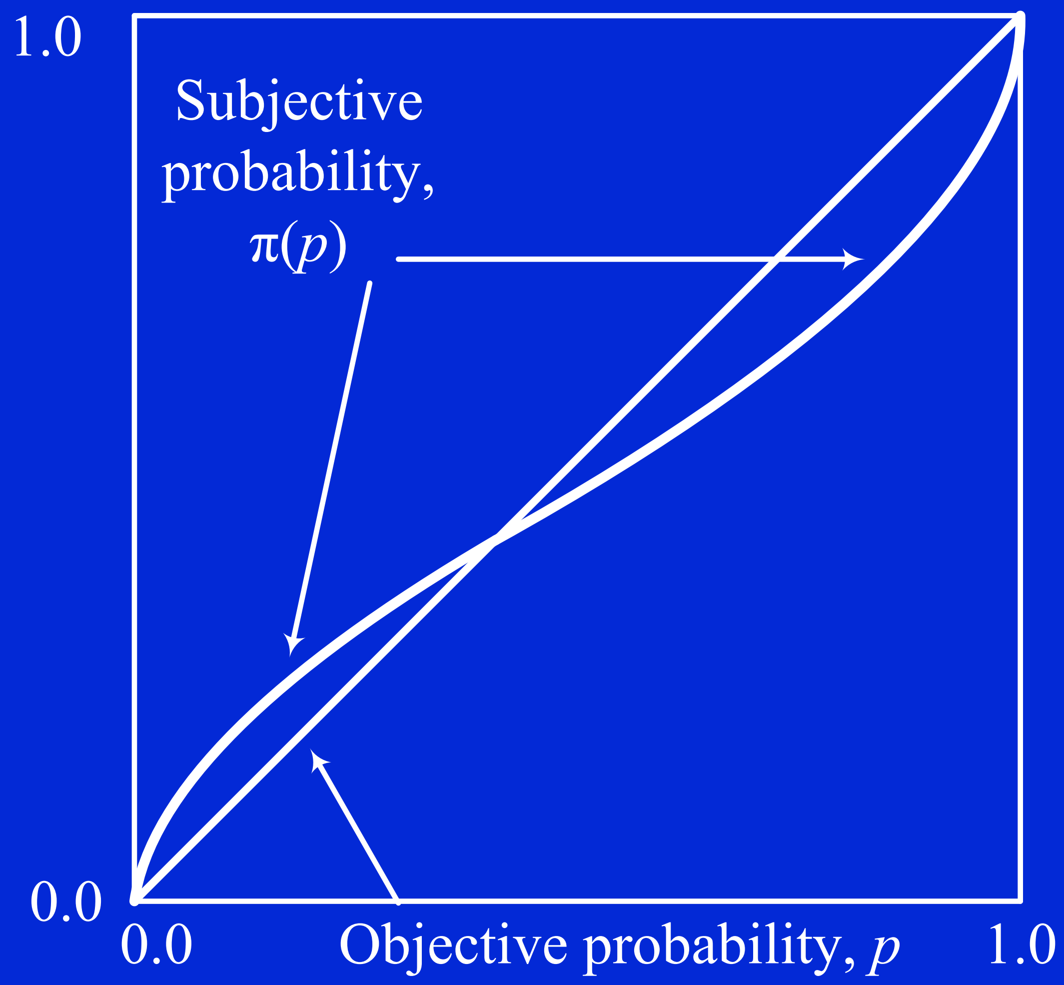
($X^2$ = 22, Logistic

# *Implication of Prospect Theory for the Risk Matrix*



# 3a. Asymmetrical Probability Bias

- **Subjective probability transformation**
- **π(*p*) predicts that likelihood data will be pushed toward L = 3**
  - **Large probabilities translated down more than small probabilities are translated up**
  - **➢Reduced amount of large subjective probabilities, comparatively**




| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 58 | 272 | 754 | 288 | 40 |

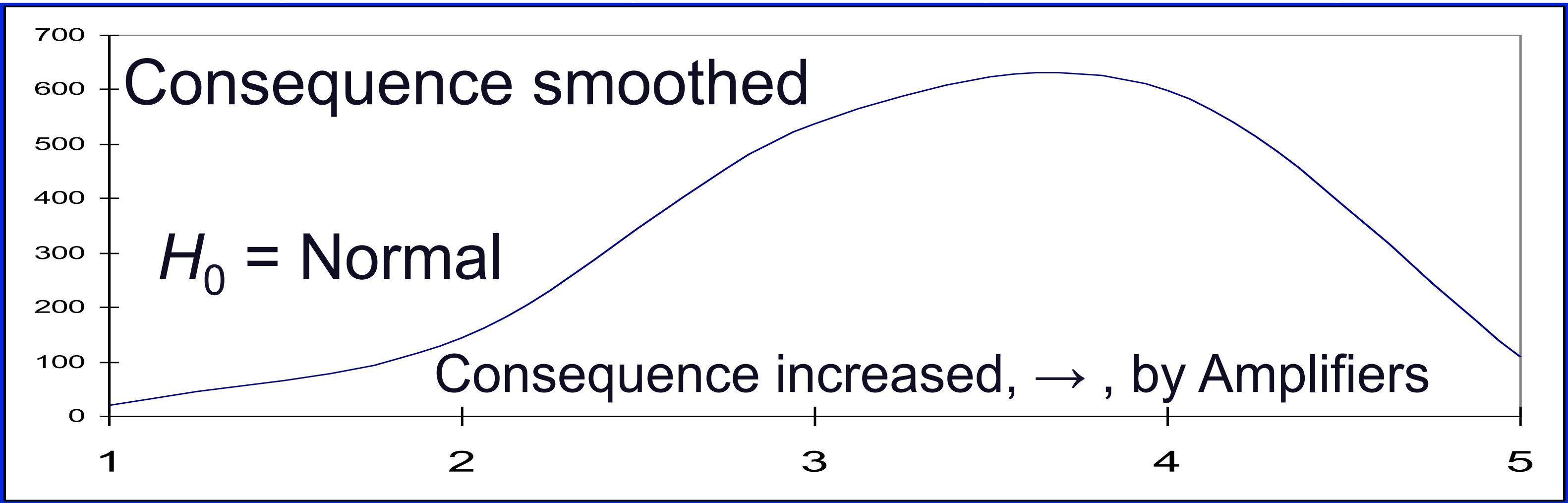
# Statistical Evidence for Consequence Bias

**Max at C = 4**

**C = 1 significantly less than C = 5 counts**

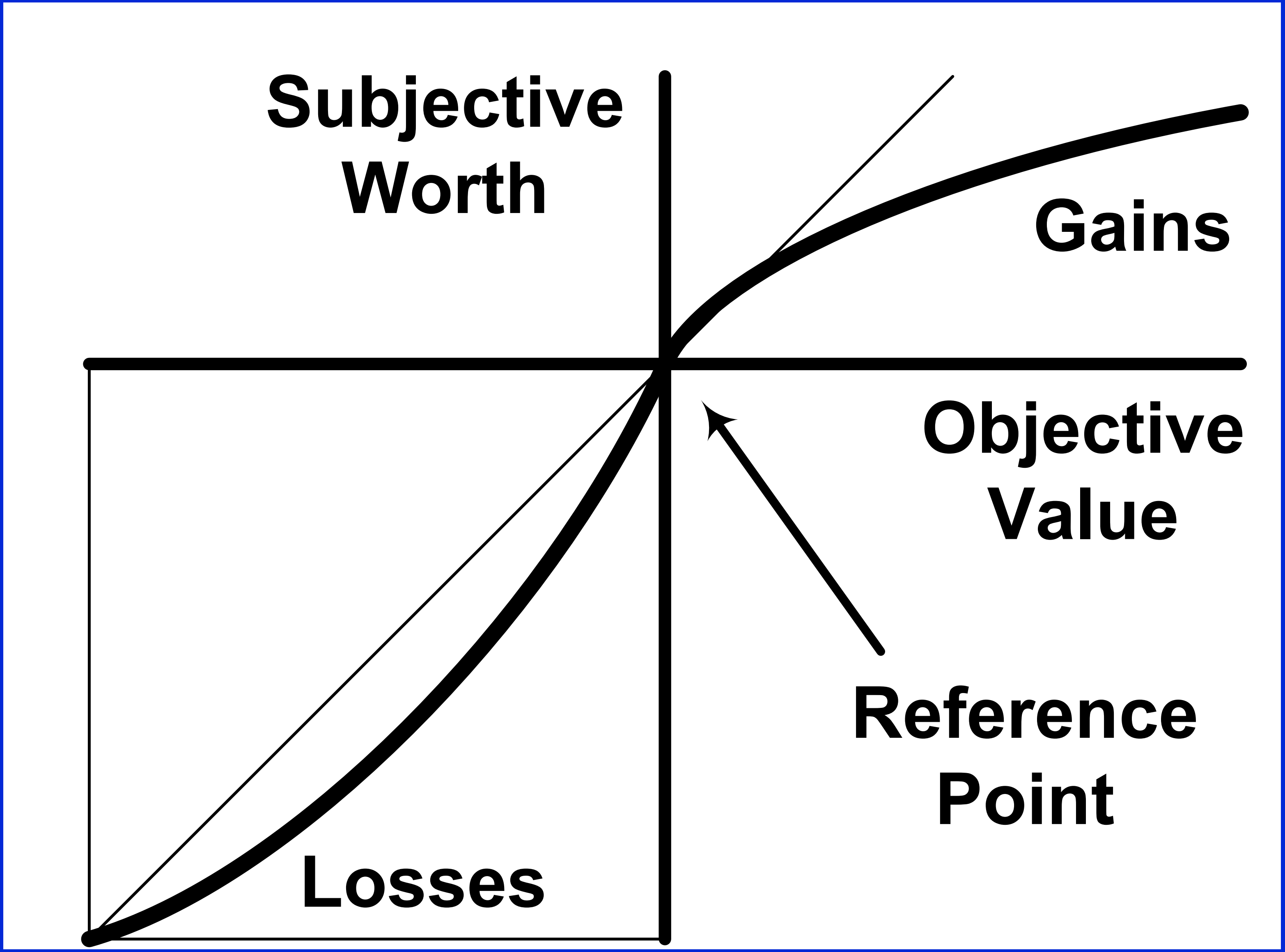
**C = 2 significantly less than C = 4**

| Consequence Original Data Points | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 20 | 145 | 538 | 599 | 110 |




Normal distribution comparison: $\chi 2 = 600$, $df = 4$ → 0.0 probability

# Consequence translation



# Data Collection Improvements

- Continuum of data from
  - Risk management to
  - (Issue management)
  - Opportunity management

- Different databases
  - years of data in each

- Time
  - Waterfall Risk charts

# Future work

- Confirmation of the presence of
  - probability biases, and
  - value biases in
  - risk data from other industries or companies
- Real world effects on industry from using biased risk mitigation data
  - $’s, not risk points
  - Sequential ramifications
  - Prospect Theory risk gambles
- Inform decision makers about how cognitive biases affect risk assessment