MIS 64036: Business Analytics

Lecture II

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Course Timeline

Date	Topic Description
28 August	Introduction to Big Data and Business Analytics
4 September	Labor Day: No Class
11 September	Role of data analytics in strategic management
18 September	Descriptive Analytics: key statistics and distribution
25 September	Descriptive Analytics (cont.) + Intro to data visualization
2 October	Preparing data for modelling
⋮	⋮

Agenda

- Introduction To Decision Making Strategies
- Decision Theories
- Cognitive Heuristic & Biases
- Counteracting Cognitive Biases Using Data Analytics

Lecture Objective

- Today, we will examine common decision making strategies and theories and the assumptions ad shortcomings of each model/theory.

- In addition, we will briefly examine some of the cognitive heuristic & biases that affect our decision making process.

- This will help you better understand and appreciate the role of data analytics for decision making especially in areas of strategic management.

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- Introduction To Decision Making Strategies
- Decision Theories
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Common Decision Making Strategies By Humans

- Optimizing
- Satisficing
- Selection by Elimination
- Sole Decision Rule
- Incrementalism and Muddling Through

Decision Making Strategies: Optimizing

- Select the course of action with the highest payoff
- Simultaneous or joint comparison of costs and benefits of all alternatives
- High information processing load on humans
- According to Newell-Simon human information processing model, humans do not have the ``wits to maximize''. Therefore, people often:
    - Do not consider all alternatives
    - Do not evaluate all alternatives thoroughly and rigorously
    - Do not consider all objectives and criteria

Decision Making Strategies: Satisficing

- Decision-makers satisfice rather than maximize. They choose courses of action that are ``good enough”

- Less complex compared to optimization, but still can be quiet hard. E.g. the simple classic Farmer-Wolf-Goat-Cabbage riddle problem.

Problem: Farmer to cross the river.

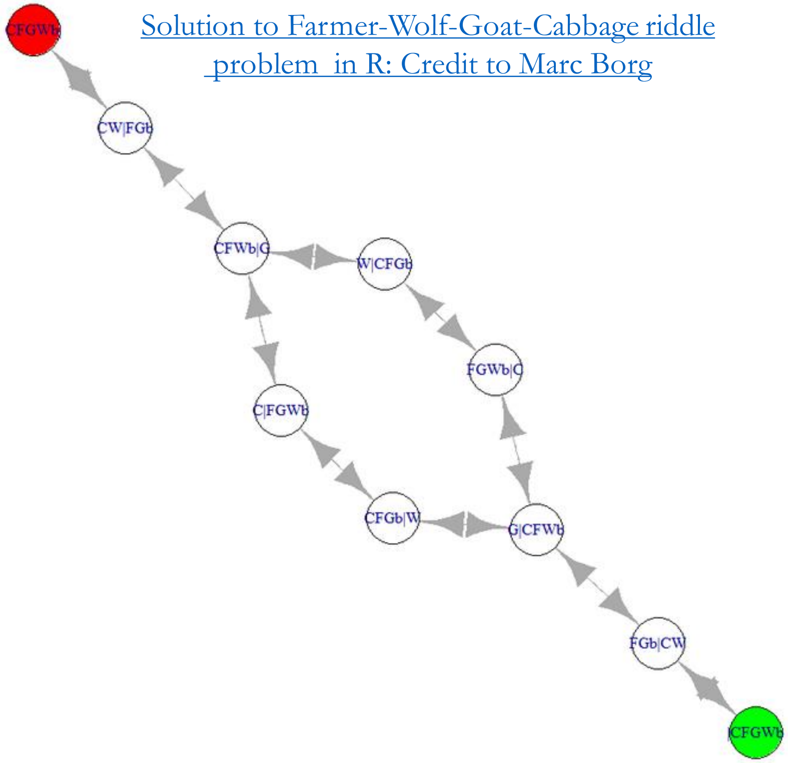
Constraints:

- Boat capacity 2
- Goat eats cabbage if left alone
- Wolf eats Goat if left alone

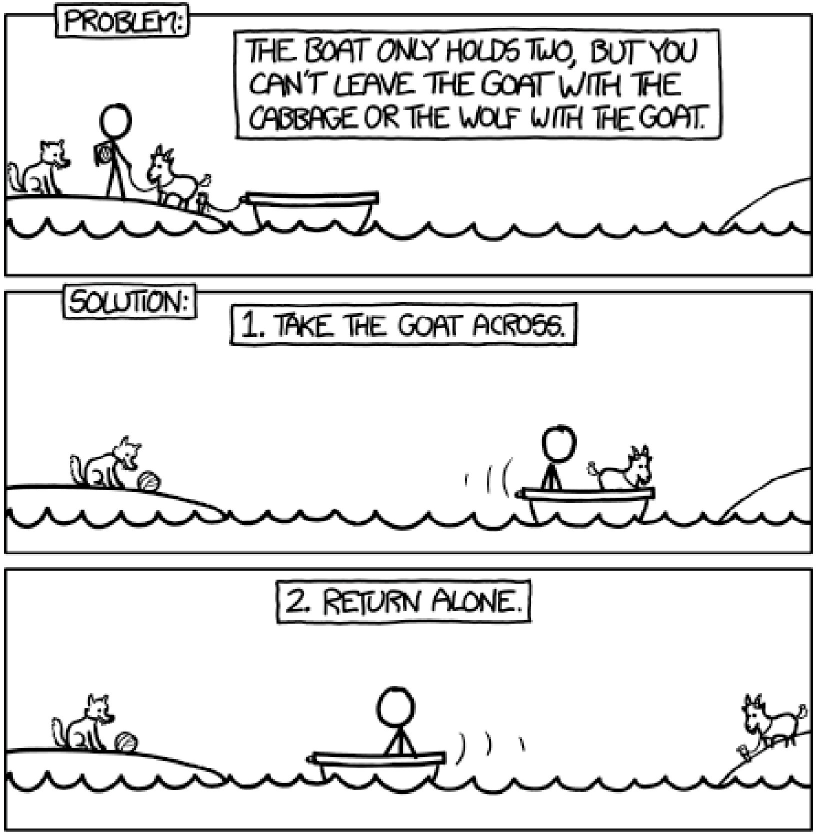
Decision Making Strategies: Satisficing (cont.)

- The problem space is very small (4 variables and 2 constraints), but still can be complex to solve.
- Now imagine the Farmer-Fox-Chicken-Spider-Caterpillar-Lettuce puzzle!
- Algorithms can solve many of these problems in fraction of seconds. Problem formulation is key though.

[Solution to Farmer-Wolf-Goat-Cabbage riddle problem in R: Credit to Marc Borg]



An Alternative (and Perhaps a Better) Solution !



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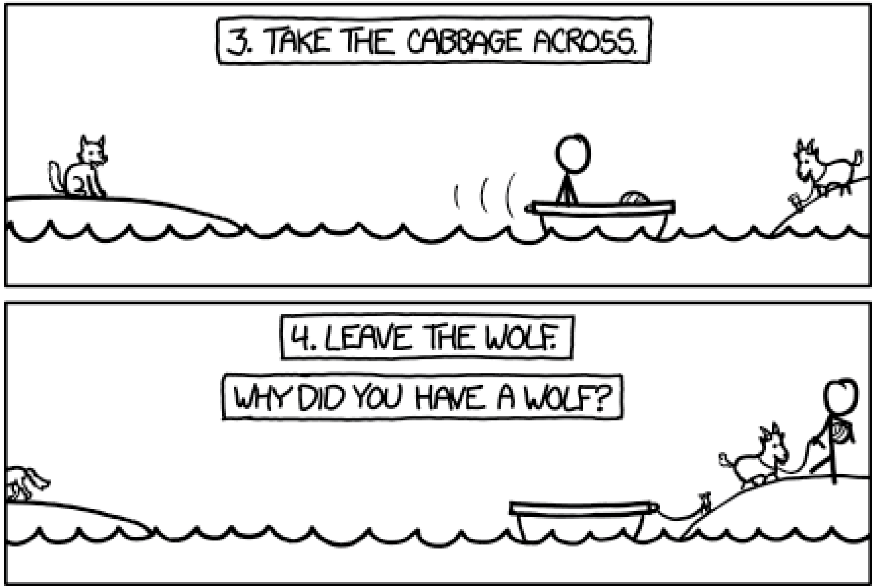


Often times the organizations don’t know their actual problem !

Decision Making Strategies: Selection by Elimination

- Eliminate alternatives that do not meet the most important criterion (screening; elimination by aspects)
- Repeat process for the next important criterion, and so on
- Decision-making becomes a sequential narrowing down process
- ``Better'' alternatives might be eliminated early on---improper weights assigned to criteria
- Decision-maker might run out of alternatives

Solving Farmer-Wolf-Goat-Cabbage Riddle Problem by Elimination

- We can solve the problem by creating a list of all possible moves at each valid state and move to the next state until the desired state is found.

- To Solve the problem, we need:
  - To formulated the problem
  - Defines the constraints
  - Create a mechanisms to track and evolve candidate solutions

- The next few slides are examples of how the problem can be formulated and solved using R. You are not expected to understand all of the code details though (Not part of the course).

Problem Formulation

- We represent the status of the Wolf, the Goat, the Cabbage and the Farmer using R data frames.

- Different rows show the problem state at different steps (1=present, 0=not present), where the current state is represented by the last row.

Wolf@ Left Side of the River

	W_L	G_L	C_L	F_L	W_R	G_R	C_R	F_R
Step 1: Everyone is @ left at start	1	1	1	1	0	0	0	0
Step 2: Goat & Farmer Move to right	1	0	1	0	0	1	0	1
Step 3: Farmer comes back to left	1	0	1	1	0	1	0	0

⋮

Define Constraints

- Starting State:

W_L	G_L	C_L	F_L	W_R	G_R	C_R	F_R
1	1	1	1	0	0	0	0

- End State

W_L	G_L	C_L	F_L	W_R	G_R	C_R	F_R
0	0	0	0	1	1	1	1

- Wolf and Goat can not both present at either side without the presence of Farmer

```
if (sum(s[1],s[2])==2 & s[4]==0) {result=0}
if (sum(s[5],s[6])==2 & s[8]==0) {result=0}
```

- Goat and Cabbage can not both present at either side without the presence of Farmer

```
if (sum(s[2],s[3])==2 & s[4]==0) {result=0}
if (sum(s[6],s[7])==2 & s[8]==0) {result=0}
```

Define Constraints

- the Wolf, the Goat, the Cabbage and the Farmer can only be at 1 side of the river at each given time.

```
S_numeric=as.numeric(S)
N=length(S_numeric)

if (!all(head(S_numeric,N/2)+tail(S_numeric,N/2)==rep(1,N/2))){result=0}
```

- That is the abstract way of saying

```
if (sum(S[1],S[5])!=1) {result=0}
if (sum(S[2],S[6])!=1) {result=0}
if (sum(S[3],S[7])!=1) {result=0}
if (sum(S[4],S[8])!=1) {result=0}
```

Define Constraints

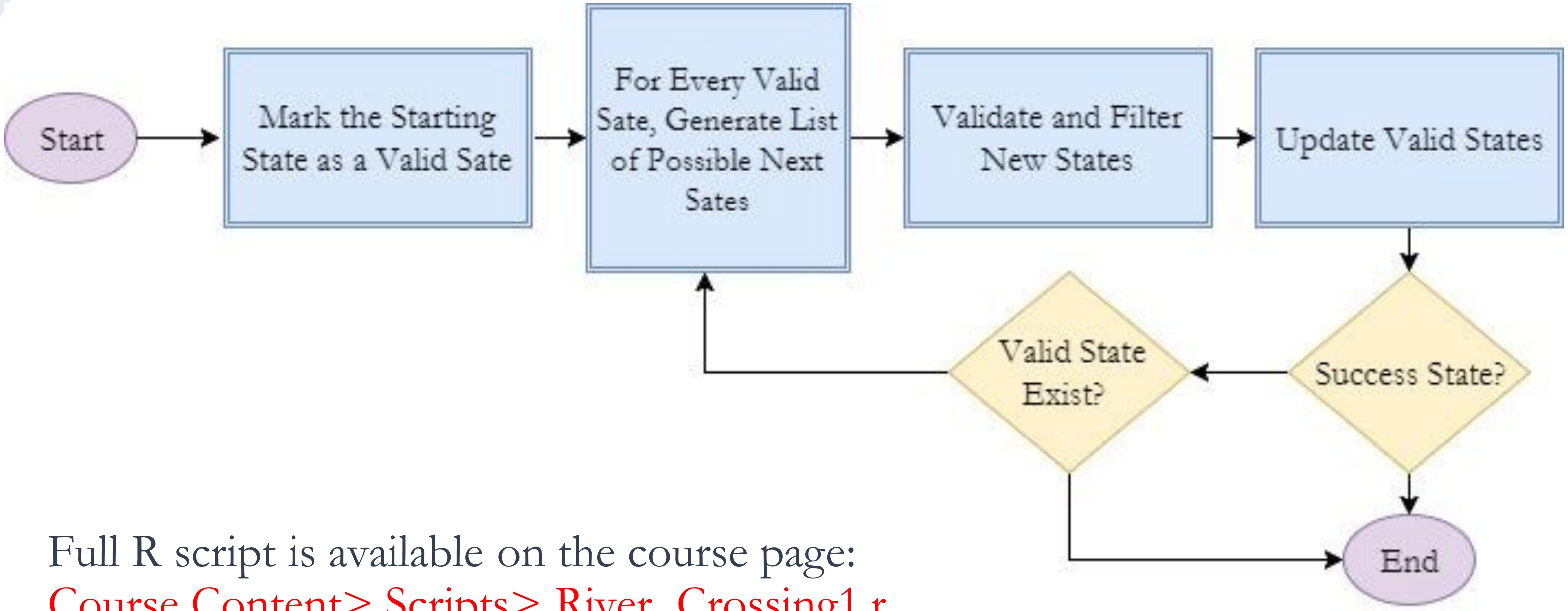
- From each step to the next, the location of the farmer should change (right to left and left to right) and only the animals/item that are on the same side as the farmer can be moved

```
M_Left <- as.data.frame (expand.grid(rep(list(0:1),N)))
for (m in 1:ncol(M_Left)){
  M_Left[,m]= M_Left[,m]*as.numeric(S[,m])
}
M_Left=unique(M_Left)
M_Left<-cbind(M_Left,0)
```

- The maximum number of items that can be moved (including the farmer) at each step is defined by the boat capacity

```
Delta=rep(0,nrow(M))
for (m in 1:nrow(M)){
  Delta[m]=sum(abs(as.numeric(M[m,])-as.numeric(S)))
}
M=M[Delta<=2*Boat_Capacity,]
```

Top Level Overview



Full R script is available on the course page:
Course Content> Scripts> River_Crossing1.r

Solution & Comments

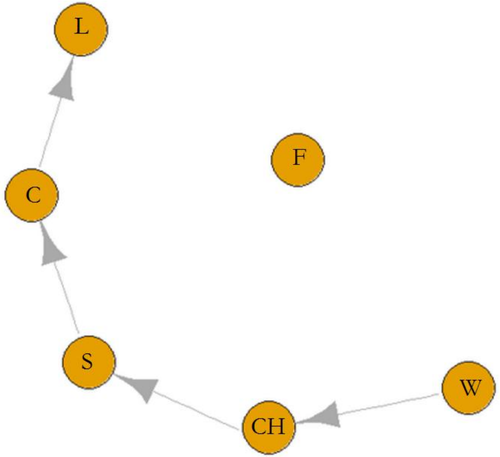
- Final solution: (7 Trips)

- We could solve this without computer modeling.

- But now consider the Farmer-Wolf-Chicken-Spider-Caterpillar-Lettuce problem where the boat capacity is 3.

- In addition, with a model, you can answer many different types of question related to the problem. e.g. “What if” type of questions.

```
[1] "####Solution Found######"
  W_L G_L C_L F_L W_R G_R C_R F_R
1   1   1   1   1   0   0   0   0
2   1   0   1   0   0   1   0   1
3   1   0   1   1   0   1   0   0
4   1   0   0   0   0   1   1   1
5   1   1   0   1   0   0   1   0
6   0   1   0   0   1   0   1   1
7   0   1   0   1   1   0   1   0
8   0   0   0   0   1   1   1   1
```



Solution & Comments

- Solution to the Farmer-Wolf-Chicken-Spider-Caterpillar-Lettuce. (Script on the course page, River_Crossing2.r)

```
[1] "####Solution Found######"
  W_L CH_L S_L C_L L_L F_L W_R CH_R S_R C_R L_R F_R
1   1    1   1   1   1   1   0    0   0   0   0   0
2   1    0   1   0   1   0   0    1   0   1   0   1
3   1    1   1   0   1   1   0    0   0   1   0   0
4   0    1   0   0   1   0   1    0   1   1   0   1
5   0    1   0   1   0   1   1    0   1   0   1   0
6   0    0   0   0   0   0   1    1   1   1   1   1
```

- What if the boat capacity was 4?

```
[1] "####Solution Found######"
  W_L CH_L S_L C_L L_L F_L W_R CH_R S_R C_R L_R F_R
1   1    1   1   1   1   1   0    0   0   0   0   0
2   0    1   0   1   0   0   1    0   1   0   1   1
3   1    1   0   1   0   1   0    0   1   0   1   0
4   0    0   0   0   0   0   1    1   1   1   1   1
```

Considerations

- Consider the Farmer-Wolf-Chicken-Spider-Caterpillar-Lettuce problem. If each single river crossing costs 50$ and the worth of each animal/item is
  - Wolf: $150
  - Chicken: $300 (I know !! :)
  - Spider: $25
  - Caterpillar: $10
  - Lettuce: $6
- What would be the best course of actions? Now consider this in a practical business environment where you probably have tens (if not hundreds) of variables and constraints.

Considerations

- Practical business problems are much harder to formulate.
  - Many more variables
  - Many more constraints
  - Multi-objective problems (mostly contradicting goals)
  - Uncertainty, subjectivity and loosely defined relationships
  - Variability over the time
- Modelling is especially useful when
  - The problem is important and complex
  - There is a need for frequent use of the model
  - The model can produce solutions but also useful insights

Decision Making Strategies: Sole Decision Rule

- ``Tell a qualified expert about your problem and do whatever he (she) says---that will be good enough"
- Rely upon a single formula as the sole decision rule
- Use only one criterion for a suitable choice e.g., do nothing that may be good for the enemy
- Impulsive decision-making usually falls under this category

Decision Making Strategies: Incrementalism

- Often, decision-makers have no real awareness of arriving at a new policy or decision
- Decision-making is an ongoing process
- The satisficing criteria themselves might change over time
- Make incremental improvements over current situation and aim to reach an optimal situation over time
- Frequently found in pluralistic societies and organizations

Are You Still Thinking About That $300 Chicken?

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- Cognitive Heuristic & Biases
- Counteracting Cognitive Biases Using Data Analytics

Decision Theories

We will briefly review the following decision theories:

- Rational Choice Theory
- Utility Theory
- Bounded Rationality

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Rational Choice Theory

Von Neumann & Morgenstern (1947) attempted to remove psychological assumptions from the theory of decision making:

- Individuals have precise information about the consequences of their actions
- Individuals have sufficient time and capability to weigh alternatives
- All decisions are "forward looking"
- "Game theory" is RCT in practice

Rational Choice Theory

Utility Theory

- Utility Theory determines how preferences are determined within RCT
- Strictly construed, UT assigns a common currency (utility) to disparate outcomes
- In this context, the utility is a quantitative measure of the attractiveness of a potential outcome
- The objective is to maximize this utility
- Under uncertainty, the "value" of a choice is the expected value of probabilistic outcomes

St. Petersburg Paradox

- You pay a fixed fee to enter the game. Then a fair coin is tossed repeatedly until a tail appears, ending the game.
- The pot starts at 1 dollar and is doubled every time a head appears. You win whatever is in the pot after the game ends.
- The expected gain is unlimited so, theoretically, you should pay any price to play the game. How much would you pay to play?

$$
\begin{aligned}
E &= \frac{1}{2}\times 1+\frac{1}{4}\times 2+\frac{1}{8}\times 4+\frac{1}{16}\times 8+\dots \\
&= \frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\dots \\
&= \infty
\end{aligned}
$$

https://plato.stanford.edu/entries/paradox-stpetersburg/

Utility Theory

Bounded Rationality

- Acknowledges several limitations of UT and RCT as descriptive models of individual choice
- People lack:
  - Perfect information of outcomes and probabilities
  - Consistent utility functions across domains
  - Time and cognitive capabilities to comprehensively enact the prescriptions of UT and RCT
- Experts and everyday decision makers are error-prone

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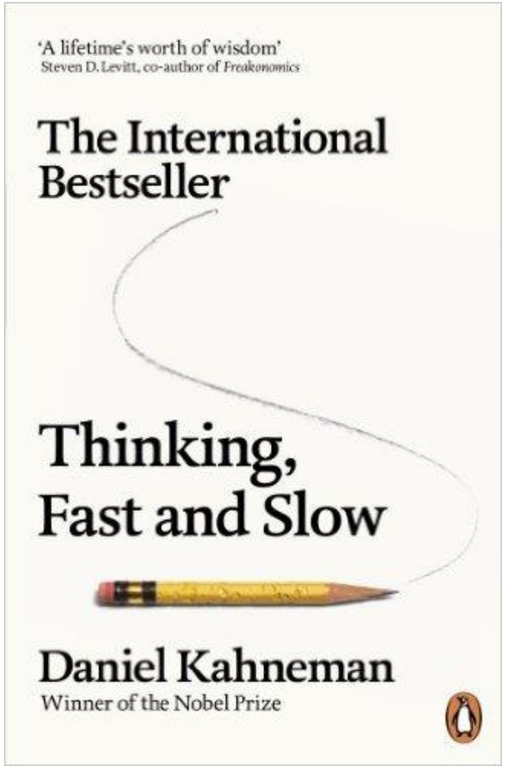
Heuristic & Biases

- RCT & UT are very bad descriptive models in many cases
- Bounded Rationality's limitations are insufficient to explain human behavior
- Sometimes information is insufficient even for BR
- More importantly, many of the human errors are systematic
- Discovering heuristic rules of judgment can explain these systematic errors

A Must-Read Book !



What is a Heuristic?

- "Mental shortcut" used in judgment and decision making
- Usually involves focusing on one aspect of a complex problem and ignoring others.
- Essential for living in an uncertain world
- But they can lead to faulty beliefs and suboptimal decisions
- By looking at errors and biases, we can learn how people are reasoning under uncertainty

Few Well-known Heuristics

- Availability Bias
- Anchoring & Adjustment Bias
- Representativeness Bias
- Confirmation Bias
- Hindsight Bias
- Framing Effect

Availability Heuristic

- Causes us to base decisions on information that is more readily available in our memories, rather than the <u>data we really need</u>.

- Consider these pairs of causes of death:
  - Lung Cancer vs Motor Vehicle Accidents
  - Emphysema vs Homicide
  - Tuberculosis vs Fire and Flames

- From each pair, choose the one you think causes more deaths in the US each year.

Availability Heuristic

Causes of Death	People's Choice	Annual US Totals	Newspaper Reports/Year
Lung Cancer	43%	140,000	3
Vehicle Accidents	57%	46,000	127
Emphysema	45%	22,000	1
Homicides	55%	19,000	264
Tuberculosis	23%	4,000	0
Fire and Flames	77%	7,000	24

(Combs & Slovic 1979,
see also Kristiansen 1983)

Availability Heuristic

- A doctor who has just diagnosed two cases of bacterial meningitis is likely to see it in the next patient, even though they only have the flu, which it resembles.
- People judge themselves more likely to be murdered than getting stomach cancer, because homicides are so frequently reported in the news (Brinol et al., 2006). In fact it is five times more likely that you will die of stomach cancer than be murdered.
- The same is true of shark attacks, which people think are relatively frequent because of media reports. In fact you're more likely to be killed by a part that's fallen off a plane, which in itself is unbelievably unlikely (Read, 1995).

People Should Learn Statistics…

Anchoring & Adjustment Heuristic

- Estimates are made by starting from an initial value (anchor) and adjusting to yield a final answer

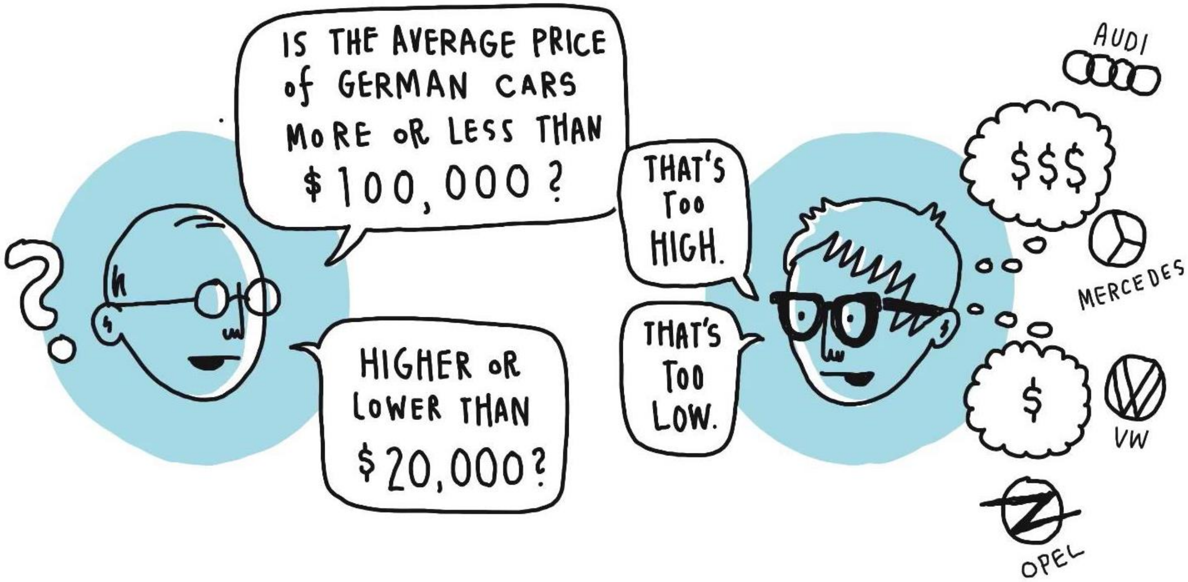
- Two groups of individuals were asked to quickly guestimate the answer to the same arithmetic problem.

  - Group 1: $1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 = ?$ Mean Answer= 512
  - Group 2: $8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = ?$ Mean Answer= 2250
  - Calculator's response : 40320

- The above confirms the anchoring bias and also our cognitive limitation (even the second group was off by factor of 18!)

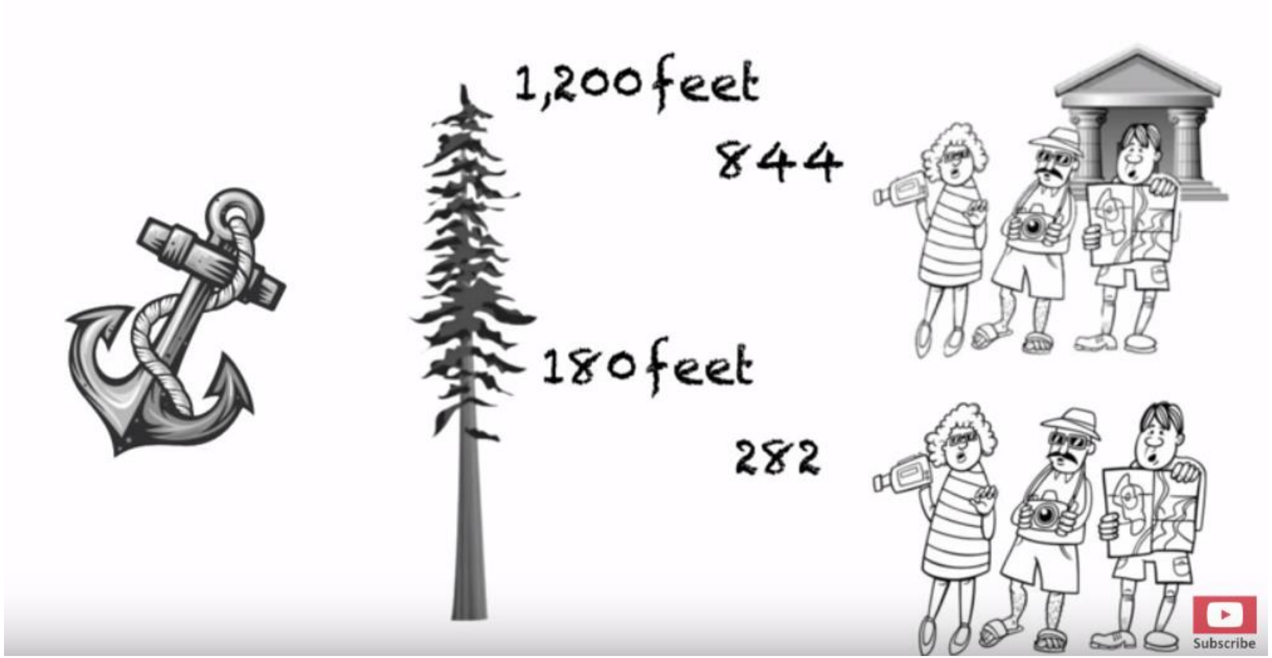
Anchoring & Adjustment Heuristic

Click here to watch the video



Anchoring & Adjustment Heuristic

[Click here to watch the video]



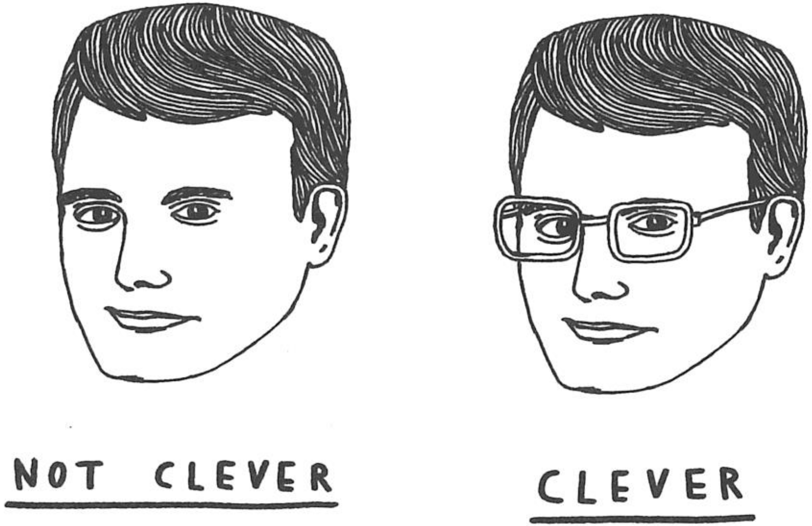
Representativeness Heuristic

- A mental shortcut that helps us make a decision by comparing information to our mental prototypes.

- Imagine a group of 70 lawyers and 30 engineers.
  - "Tom is a 30 year old man. He is married with no children. A man of high ability and high motivation, he promises to be quite successful in his field. He is well-liked by his colleagues."
  - Participants judged Tom to be equally likely to be an engineer regardless of prior probability condition. Base probability neglect!

That's Why I'm Wearing These Black Frame Eyeglasses ☺

Click here to watch the video



Confirmation Bias

- Inclines us to look for confirming evidence of an initial hypothesis, rather than falsifying evidence that would disprove it.
- Confirmation biases contribute to overconfidence effect
- Overconfidence in personal beliefs and can maintain or strengthen beliefs in the face of contrary evidence.

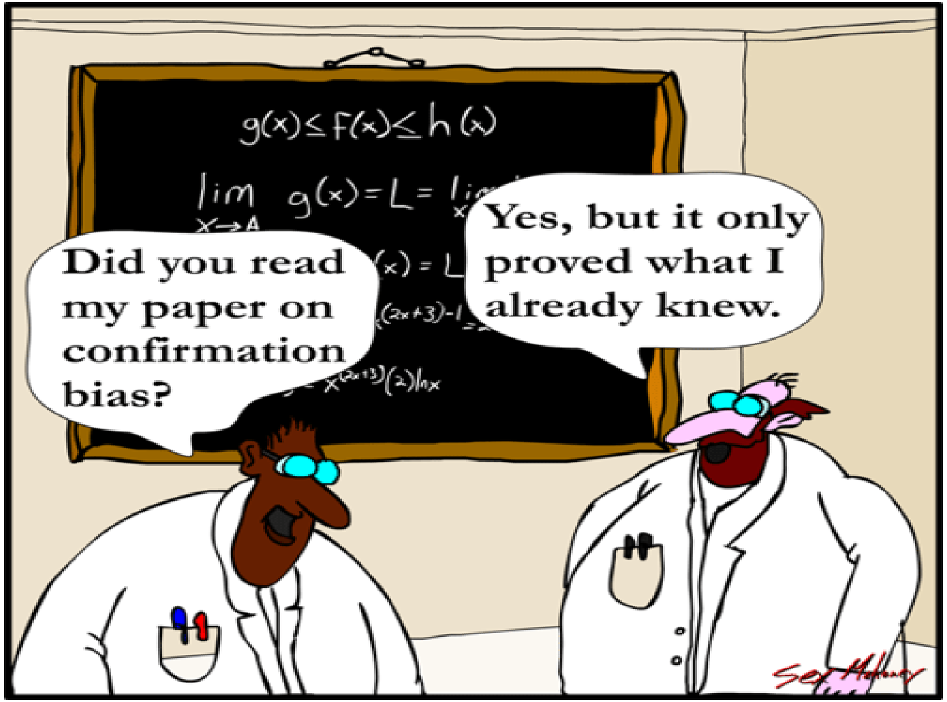
Confirmation Bias

"A man receives only what he is ready to receive, whether physically, or intellectually, or morally . . .."

- Henry David Thoreau

Confirmation Bias

[Click here to watch the video]



[Another video here]

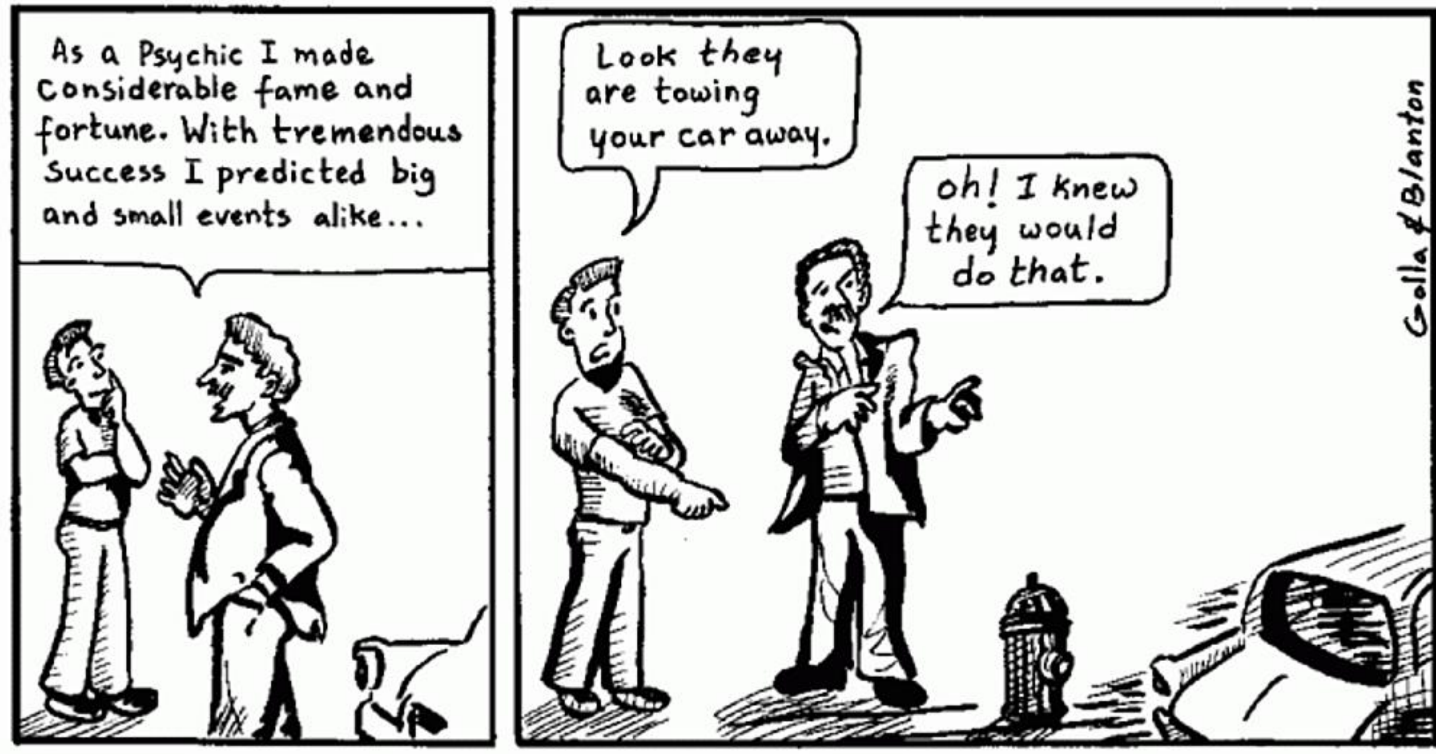
Hindsight Bias

- Causes us to attach higher probabilities to events after they have happened than we did before they happened ("I knew it all along").

- On the evening of an important World Series game, your friend predicts that the Red Sox are going to win. In fact, the Red Sox do end up winning the game, causing your friend to boast "I predicted it!"

- A letter comes in the mail informing an individual that he was accepted into a college. When he tells his mother she says, "I really had a feeling that you were going to get in" (even though she had expressed doubts to his father earlier that week !!).

Hindsight bias



Framing Effect

- Drawing different conclusions from the same information, depending on how that information is presented.

A rare disease has broken out, which is expected to kill 600 people. There are two possible programs to combat it, but they cannot both be used. The consequences of each are known:

A. 200 saved with certainty

B. 600 saved with a probability of .33

Which would you choose? Why?

A rare disease has broken out, which is expected to kill 600 people. There are two possible programs to combat it, but they cannot both be used. The consequences of each are known:

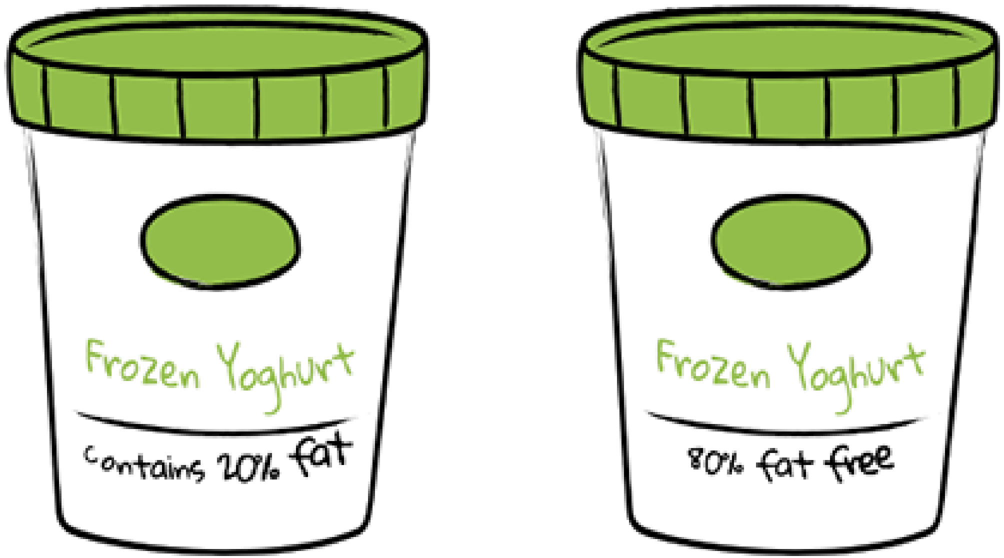
A. 400 die for certain

B. 600 die with a probability of .67

Which would you choose? Why?

Framing Effect

Click here to watch the video

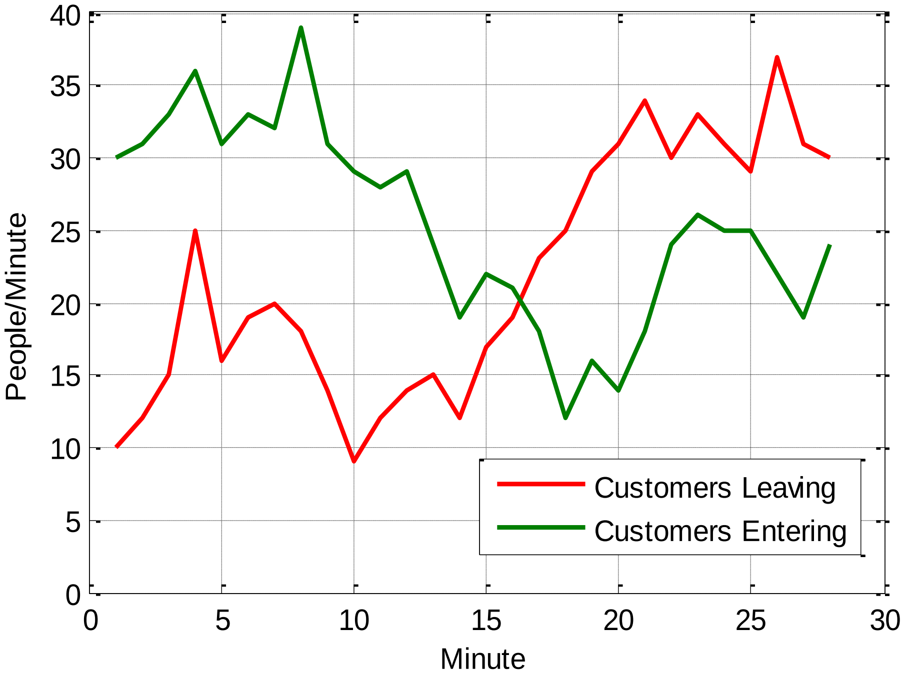


…And It's Not Only Systematic Heuristics

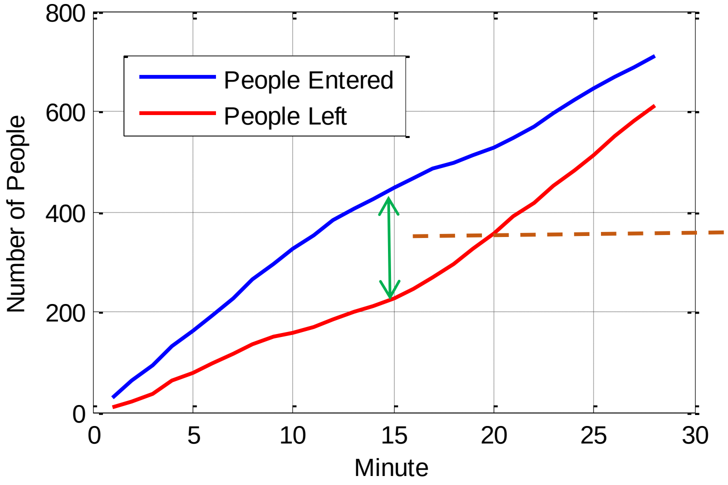
- There are many more systematic heuristics and biases. Click here for a comprehensive list.
- But there also exist non-systematic cognitive limitations that affect our understanding of the problems hence our decisions.
- Recall our inability to generate and eliminate large number of candidate solutions in the yet simple Farmer-Wolf-Goat-Cabbage Riddle Problem.
- See the next few slide for another example (The classic MIT Department Store task) .

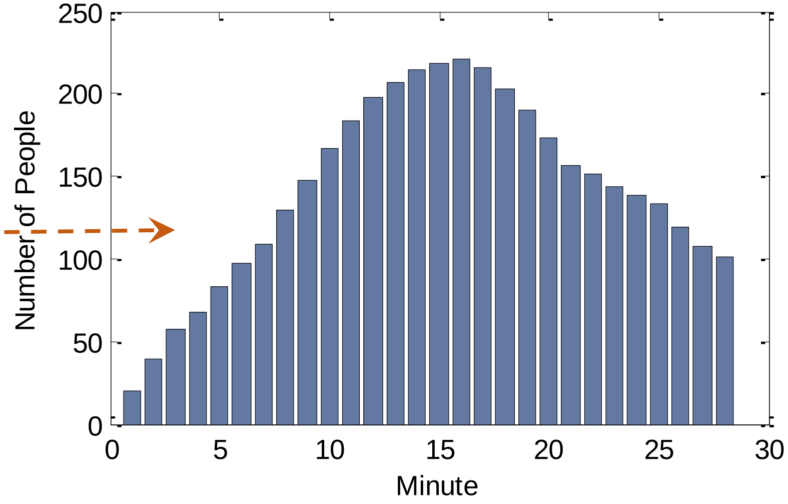
Department Store Example

- Q1: During which minute did the most people enter the store?
- Q2: During which minute were the most people in the store?
- Q3: During which minute were the fewest people in the store?
- The rate of the correct answers for MIT students: 94%, 44% and 33% for Q1, Q2 and Q3!



Department Store Example: Accumulation





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Data Analytics To Shield Against Biases

- 40% of major business decisions are not based not on data and facts, but on "gut instinct" –Accenture Research
- Extensive evidence that having experts is good, but experts using analytics is much better.
- Statistical predictions consistently outperform —gut based predictions
- Expert intuition is best only when there is little time, limited data and few variables

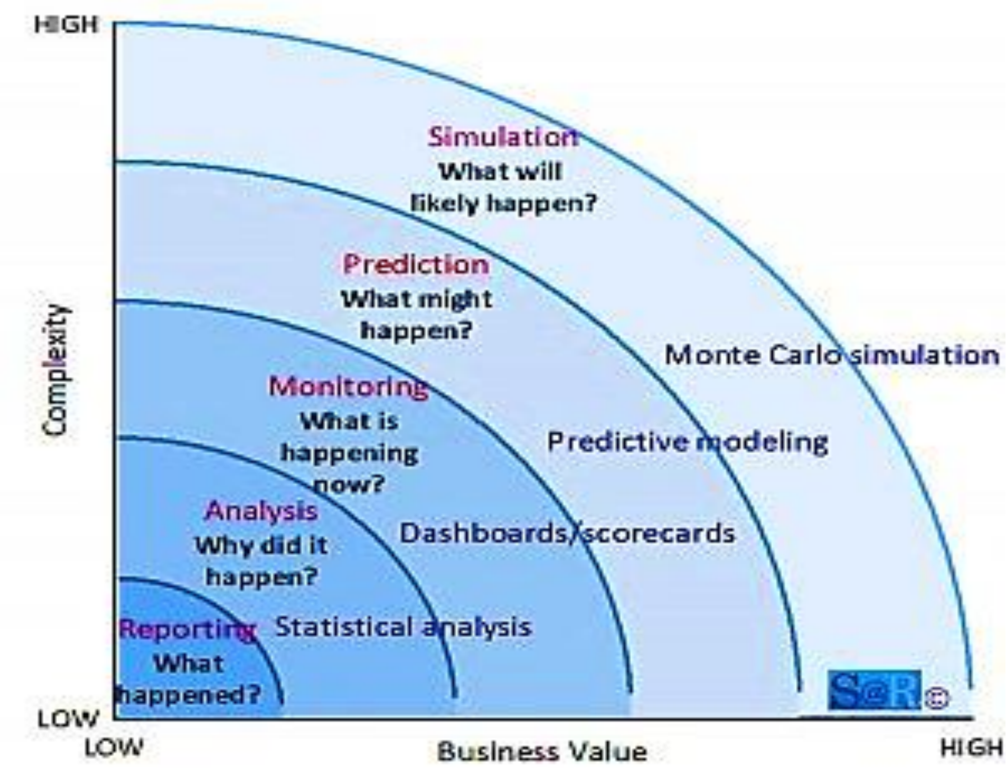
Analytics for Strategic Management*

High performers are 5 times more likely to say "Analytics is a key element of our business strategy" than low performers

Low Performers		High Performers
23%	Have significant decision-support/analytical capabilities	65%
8%	Value analytical insights to a very large extent	36%
33%	Have above-average analytical capability within industry	77%
23%	Use analytics across their entire organization	40%

* From Accenture Research

Analytics Maturity



What We Covered

- Introduction To Decision Making Strategies
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ANY
QUESTIONS
?