

Critical Thinking in Continuous Process Improvement



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Myriad Definitions of Critical Thinking

- Supreme Court Justice Potter Stewart in 1964, when asked to explain hard-core pornography or what is obscene:

“I shall not attempt today to further define that kind of material but I will know it when I see it.”

What and Why of Critical Thinking?

It is the deliberate and systematic processing of information

so that we can

solve problems,

make better decisions, and in general, just

understand things better.

Critical thinking is hard.

- It requires us to apply diverse tools to diverse information.
- It takes a lot of energy, so we need to separate the automatic thinking from the critical thinking.

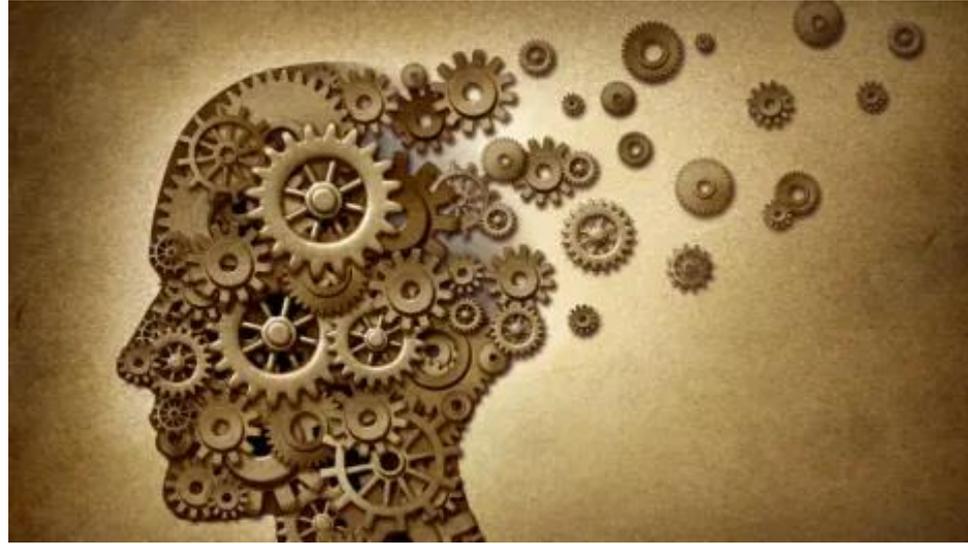
Employers value workers who know how to think critically, because they can be trusted to make decisions independently and will not need constant handholding.

Our Focus

- Barriers to Critical Thinking – we are all biased!
 - Cognitive Biases
 - Data (Statistical) Biases
- Ways to Think More Critically

What is a cognitive bias?

A cognitive bias refers to a ‘systematic error’ in the thought process.



Such biases are often connected to a heuristic.

A heuristic is essentially a mental shortcut that can ease the cognitive load of making a decision. It is what Daniel Kahneman might call “thinking fast.”

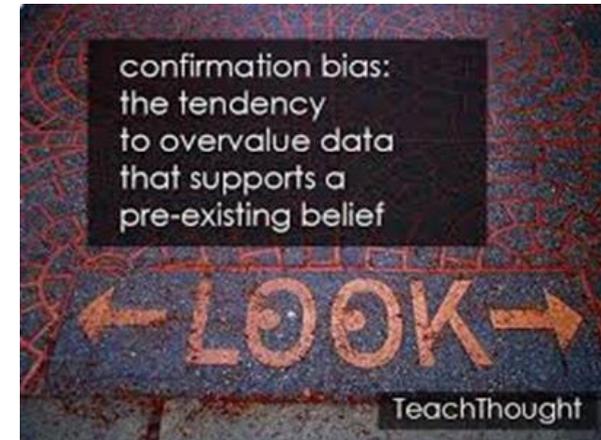
Heuristics allow one to make an inference without extensive deliberation and/or reflective judgment.

Many Different Types of Cognitive Biases

- Confirmation Bias
- Group Think
- Halo Effect
- Overconfidence Bias
- Dunning-Krueger Bias

Confirmation Bias

The tendency to interpret a situation in a manner that confirms one's beliefs



People will focus only on the information or evidence that supports their hypothesis.

Example: imagine a person holds the belief that left-handed people are more creative than right-handed people. Whenever this person meets a person who is both left-handed and creative, they place greater importance on this “evidence” that support their belief.

Example: when students are asked to write a research report, they primarily search for information that would confirm their beliefs on the topic. The student might fail to fully consider information that is inconsistent with their beliefs.

Examples of Confirmation Bias



Not seeking out objective facts



Interpreting information to support your existing belief



Only remembering details that uphold your belief



Ignoring information that challenges your belief

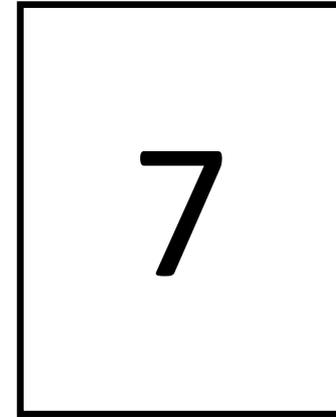
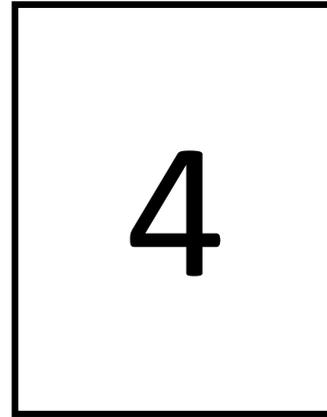
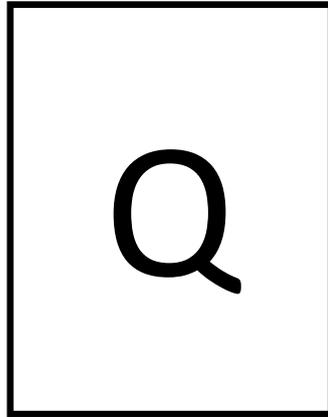
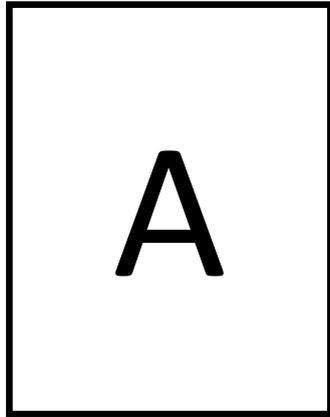
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Polling Question #1

Rule:

If a card has a vowel on one side, then it must have an even number on the other side.



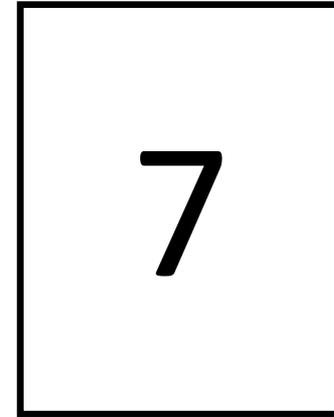
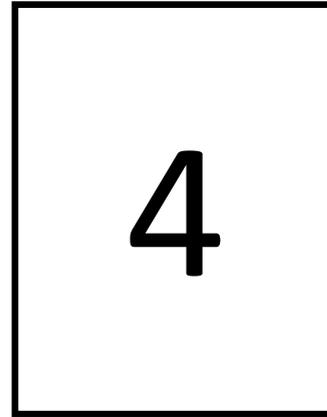
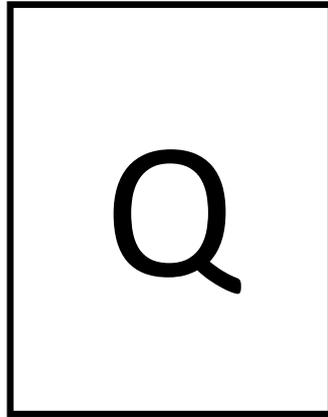
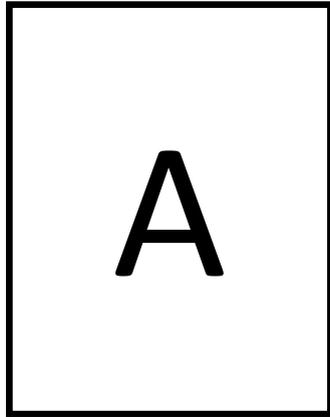
Which cards would you turn over to confirm this rule? Select one of the following responses:

1. (A, 4)
2. (A, 7)
3. (Q, 4)
4. (Q, 7)

Polling Question #1 Answer

Rule:

If a card has a vowel on one side, then it must have an even number on the other side.



Which cards would you turn over to test this rule? Select one of the following responses:

1. (A, 4)
2. (A, 7)
3. (Q, 4)
4. (Q, 7)

Logically speaking,

If p, then q is equivalent to **If ~ q, then ~ p** (this is the contrapositive of the original rule)

Group Think

The bias where extreme consensus seeking tendencies override realistic and necessary points of view, resulting in irrational or dysfunctional decision making.



It occurs when group members form an exclusive bond and create a fear of challenging group decisions and disrupting group harmony.

- Group think prevents common sense and problem-solving activities from happening. It prevents us from thinking for ourselves and making the best decisions.
- Group think stereotypes opponents as unintelligent and easily defeated.
- Examples: Bay of Pigs invasion, failure to anticipate Pearl Harbor, Space Shuttle Challenger

A Critical Thinker



- Writes weekly column in **Parade Magazine**
- Guinness Book of World Records, Highest I.Q.

“Not knowing the difference between opinion and fact makes it difficult to make good decisions.”

- Marilyn Vos Savant

Ask Marilyn (Parade Magazine)

Dear Marilyn,

Suppose I'm on a game show and the game show host shows me three doors. He says behind one door is a car and behind the other two are goats. The host asks me to select a door and suppose I choose door #2. The host will not open the door I selected, but will open one of the remaining two doors to reveal to me a goat.

The host then gives me an option and asks me, "What do I want to do?". "Do I want to stay with the door I originally chose or switch to the other unopened door?"

What should my strategy be? Should I stay, switch, or doesn't it matter?

What would you say?

Polling Question #2

Select one of the following responses that best describes your thought process with the goal of winning the car.

1. I would **STAY**.
2. I would **SWITCH**.
3. It **doesn't matter** what I do. The chances of (1) and (2) are the same.

If you have seen this problem before, recall your first impression and select that response.

Marilyn's Answer

“Yes, you should switch.”

If you switch, you'll have a two thirds chance of winning the car.

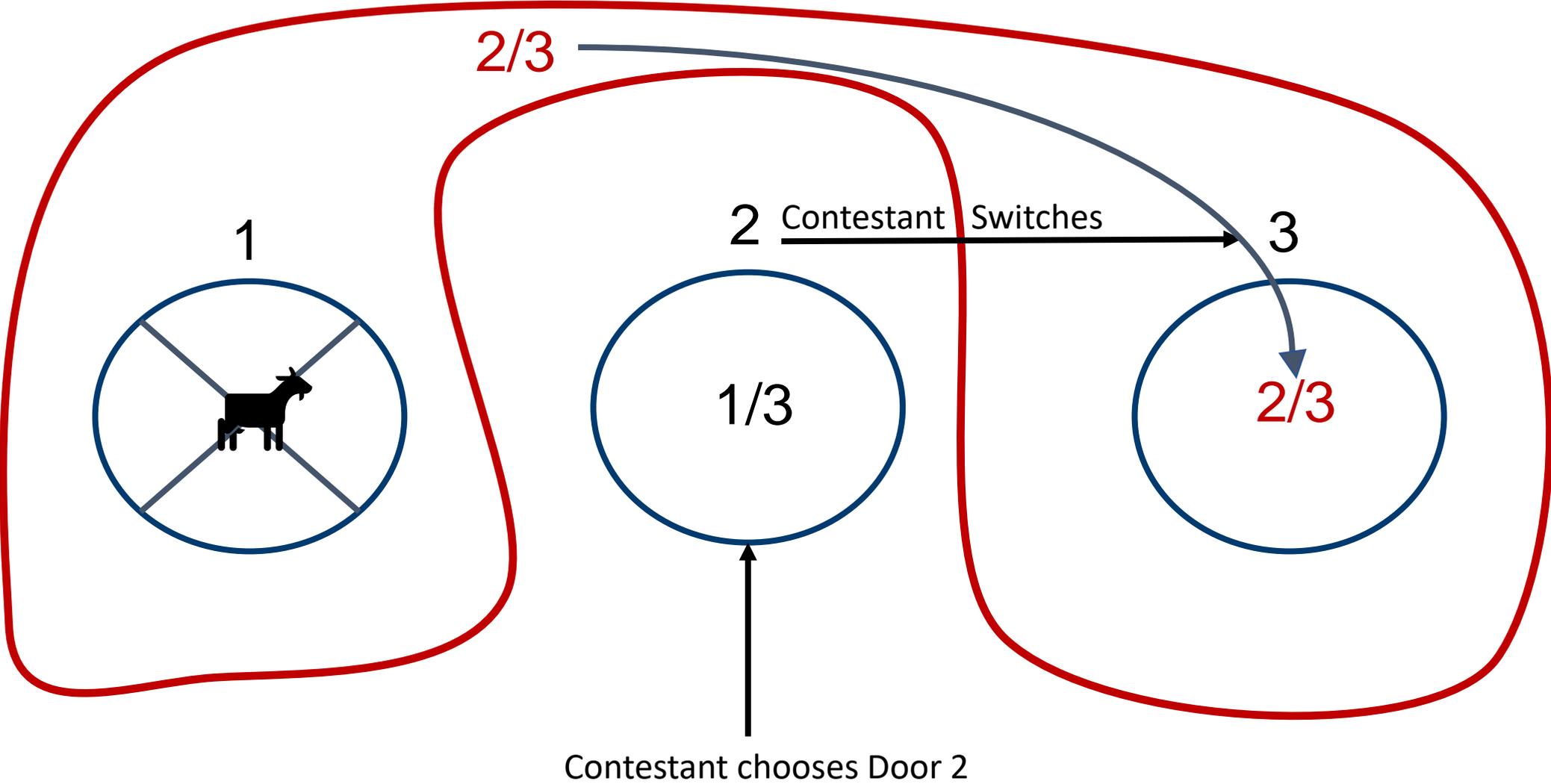
Marilyn's Advice: Get the Data

Not convinced???

Marilyn suggested to play the game yourself and see. Many websites now exist where you can participate in the simulation.

Let's see a simple explanation>>>

Another Way of Looking at the 3-door Problem



Readers Respond in Droves

Marilyn's response created what one might consider a national furor, especially among mathematicians and those who consider themselves knowledgeable in the area of probability

Here's just a sampling of some of the responses she received.....>>>>

Ask Marilyn* Reader Responses

You are in error - and you have ignored good counsel - but Albert Einstein earned a dearer place in the hearts of the people after he admitted his errors.

- Frank Rose, Ph.D., University of Michigan

I have been a faithful reader of your column and have not, until now, had any reason to doubt you. However, in this matter, which I do have expertise, your answer is clearly at odds with the truth.

- James Rauff, Ph.D. ,Millikin University

May I suggest that you obtain and refer to a standard textbook on probability before you try to answer a question of this type again?

- Charles Reid, Ph.D., University of Florida

Your logic is in error, and I am sure you will receive many letters on this topic from high school and college students. Perhaps you should keep a few addresses for help with future columns.

- W. Robert Smith, Ph.D., Georgia State University

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Ask Marilyn* Reader Responses (cont.)

You are utterly incorrect about the game-show question, and I hope this controversy will call some public attention to the serious national crisis in mathematical education. If you can admit your error, you will have contributed constructively toward the solution of a deplorable situation. How many irate mathematicians are needed to get you to change your mind?

- E. Ray Bobo, Ph.D., Georgetown University

I am in shock that after being corrected by a least three mathematicians, you still do not see your mistake.

- Kent Ford, Dickinson State University

Maybe women look at math problems differently than men.

- Don Edwards, Sunriver, OR

You are the goat! **GOAT?**

- Glenn Caldins, Western State College, CO

You're wrong, but look at the positive side. If all those Ph.D.s were wrong, the country would be in very serious trouble.

- Everett Harman, Ph.D., U.S. Army Research Institute

And here's one last letter:

Dear Marilyn:

You are indeed correct. My colleagues at work had a ball with this problem, and I dare say that most of them - including me at first - thought you were wrong!

- Seth Kaleon, Ph.D., Massachusetts Institute of Technology

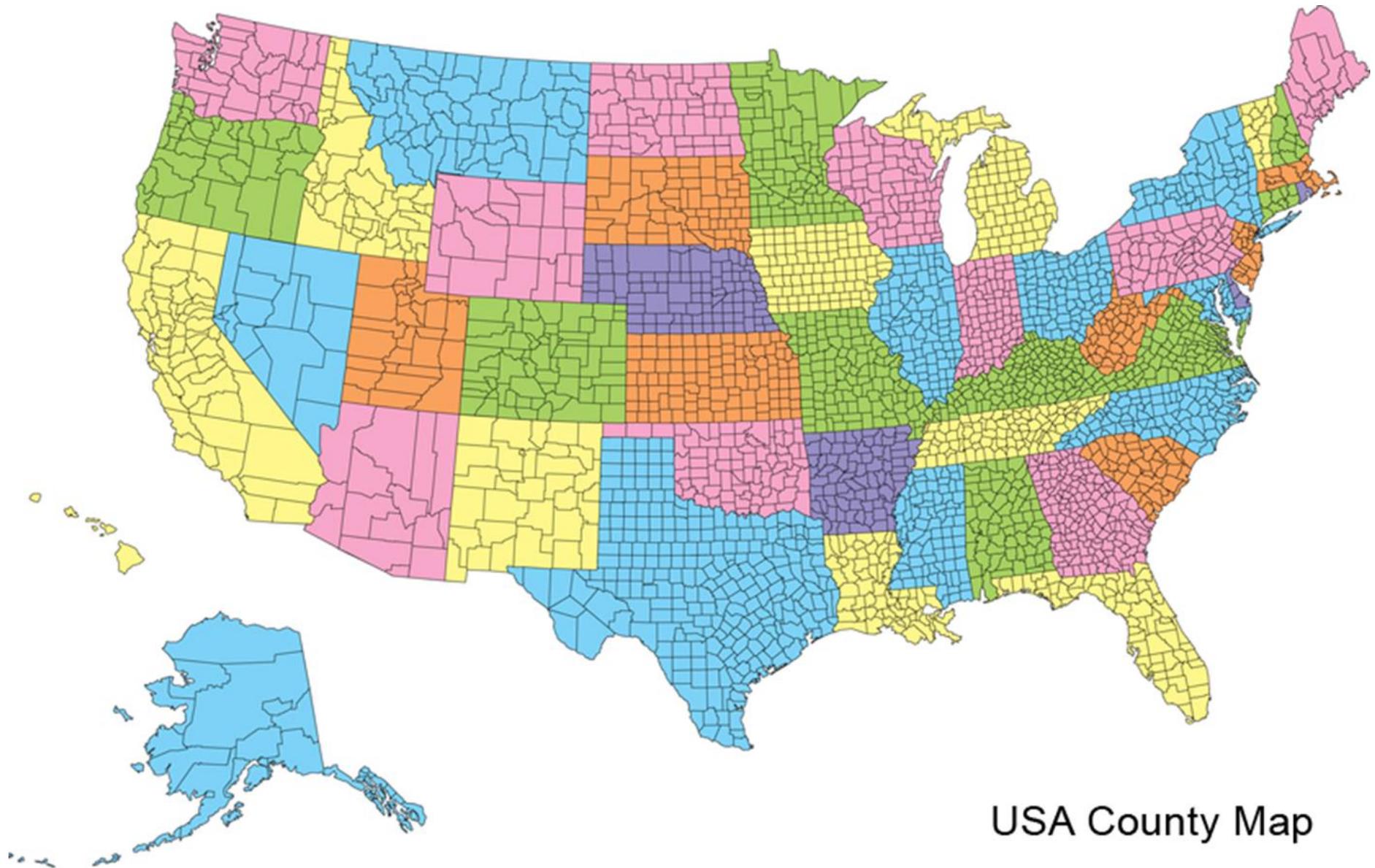
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Critical Thinking Case Study*

- A study on the incidence of kidney cancer that covered all 3,141 counties in the US revealed a remarkable pattern.
- The counties in which the incidence of kidney cancer is **LOWEST** revealed the following:
 - Mostly rural, sparsely populated counties
 - Located in traditionally Republican states
 - In the Midwest, South, and West
- At this point, what are you thinking?

* Adapted from “The Dangers of Fast Thinking” by Daniel Kahneman. THE WEEK, February 10, 2012, pp. 36-37.

Critical Thinking Case Study (cont.)



USA County Map

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Critical Thinking Case Study (cont.)

- A study on the incidence of kidney cancer that covered all 3,141 counties in the US revealed a remarkable pattern.
- The counties in which the incidence of kidney cancer is **HIGHEST** revealed the following:
 - Mostly rural, sparsely populated counties
 - Located in traditionally Republican states
 - In the Midwest, South, and West
- Now what are you thinking?

Critical Thinking Case Study (cont.)

- The rural lifestyle cannot explain both a very high and a very low incidence of kidney cancer.
- The key factor is not that the counties were predominantly Republican or located in the west, south and midwest.
- It is that rural counties have small populations. And sampling from small populations creates more extremes than sampling from larger populations.
- The main lesson is NOT about health issues and their potential causes.
- The main lesson is about the stressed relationship between our thought process and statistics.
- The main caution is that “fast thinking” automatically and effortlessly identifies causal connections when in fact there may be none.

Critical Thinking: Simpson's Paradox

- Suppose there are two major kinds of treatment for kidney stones.
- It is known that Treatment B (83%) is more effective than Treatment A (78%), as shown in the following test of proportions that turns out to be significant at the $p = 0.042$ level. Sample sizes are equal and sufficiently large ($n=600$ for each treatment) to detect significance.

Test of Proportions	
User defined parameters	
Number of Successes for Trt A	468
Size of Sample #1 (n_1)	600
Number of Successes for Trt B	496
Size of Sample #2 (n_2)	600
Results	
Proportion Sample #1 (p_1)	0.78000
Proportion Sample #2 (p_2)	0.82667
p-value	0.04200

$(1 - p\text{Value})^*100\%$
is your percent confidence that
the proportions are not equal

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Critical Thinking: Simpson's Paradox

- Suppose that you visit your physician after the advent of a kidney stone attack, and you are presented with two alternative treatments along with the data shown on the previous page. And your physician asks which procedure you would prefer.
- What are some of the questions you might ask to help you select the best treatment for you?
- One such question might be: Are my kidney stones large or small and does the size of the stone impact the success rate of the two treatments?

Critical Thinking: Simpson's Paradox

- Your doctor searches the computer database for more information on kidney stone treatments. The doc then says that Treatment A is better than Treatment B for small size kidney stones, and Treatment A is also better than Treatment B for large size kidney stones.



- Now you are confused. How can this be? Just a minute ago, your doctor told you that Treatment B was better than Treatment A and even showed you the data and test of proportions. Your doctor then quotes the computer database by saying that for small stones, Treatment A has a 93% success rate while Treatment B has an 87% success rate. The doc goes on to state that for large stones, Treatment A has a 73% success rate while Treatment B has a 67% success rate. Your doc is now admittedly confused as well.
- But fortunately, you have been schooled in critical thinking, and you ask for the complete set of data, including all sample sizes. This is shown on the next page.

Critical Thinking: Simpson's Paradox

	Small Stones	Large Stones	Total
Treatment A	140/150	328/450	468/600
	93%	73%	78%
Treatment B	402/460	94/140	496/600
	87%	67%	83%
Total	542/610	422/590	964/1200
	89%	72%	80%

- Note the imbalance in sample sizes between size of stone and the treatment. Treatment A was performed much more frequently on Large Stones, while Treatment B was performed much more frequently on Small Stones, for which the overall success rate is much better. In this case, Stone Size is a lurking variable which confounds the overall result. This phenomenon of percentage reversal is called Simpson's Paradox. This illustrates one more reason why we need Design of Experiments (DOE).

7 Ways to Think More Critically

1. **Confront your personal biases head on and unmask them.**
2. **Get the facts and data (the evidence) and analyze it properly.**
 - Who gathered the data?
 - How did they gather it?
 - Why did they gather it?
 - Who paid for the data collection (the evidence)?
 - Has a measurement system analysis been accomplished to determine the reliability of the data?
3. **Understand the difference between random variation and special cause.**

H_0 : Red (HS football) = Blue (HS football)

H_1 : Red (HS football) \neq Blue (HS football)

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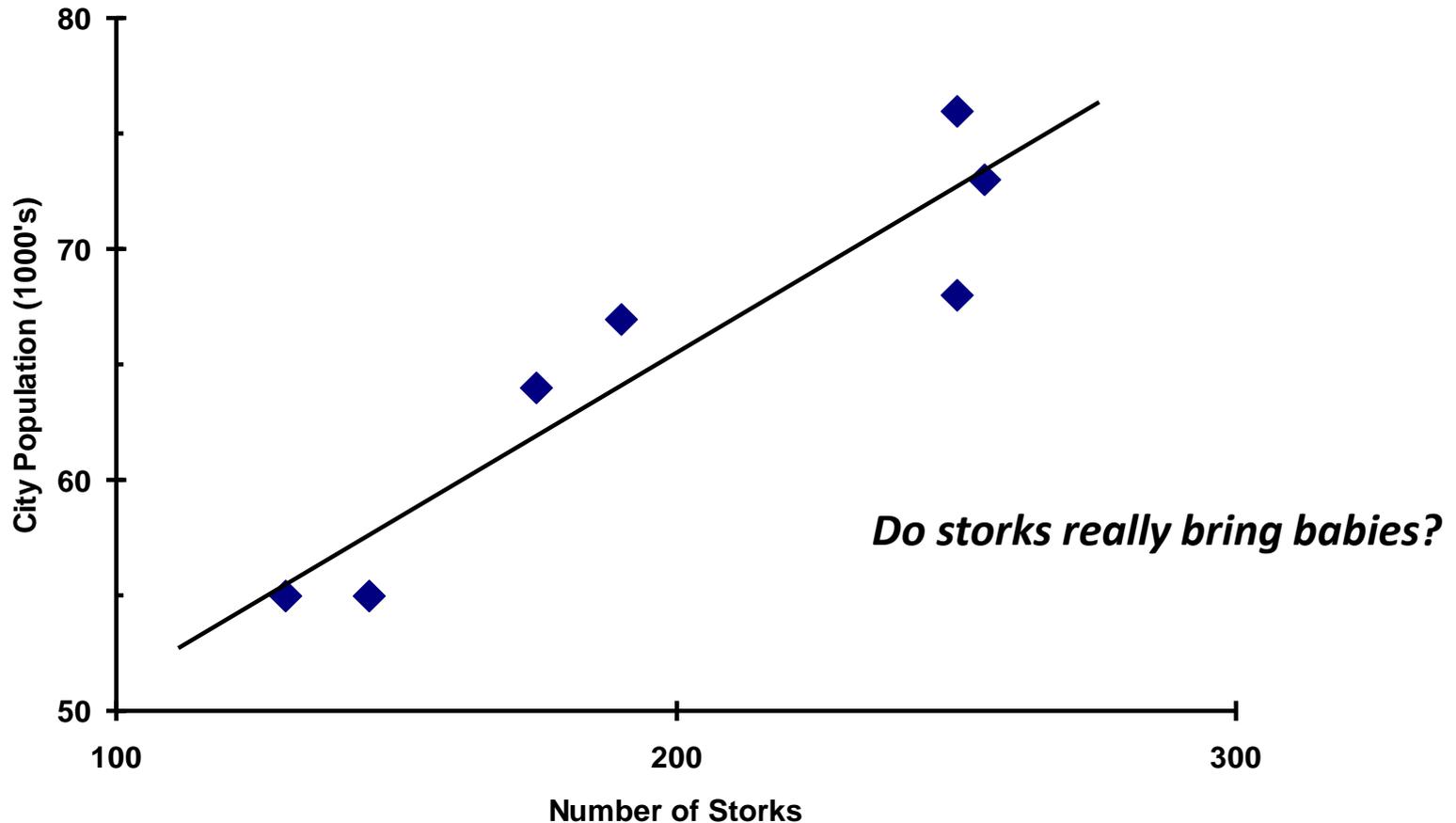
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A Test of Hypothesis for proportions shows p-value = .000

This means we can be 99.9% confident this difference is not due to random variation but is due to special cause.

7 Ways to Think More Critically

4. Understand the difference between correlation and causation.



A plot of the population of Oldenburg, Germany, against the number of storks observed at the end of each year for the years 1930-1936.

Source: "Statistics for Experimenters"
by Box, Hunter, and Hunter. (1978)

7 Ways to Think More Critically

5. Understand that there is always more than one contributing variable or cause for a situation or problem under study – variable interaction effects can be enormous (Takata airbags), especially in biological and chemical systems.

- Takata Airbag Defect Findings from the International Testing Coalition (ITC):
 - ITC says exposure to **heat** and **humidity**, and the use of **ammonium nitrate** are all required to produce what the commission and the National Highway Traffic Safety Administration (NHTSA) call an “energetic disassembly.”
 - “You can’t have the energetic disassembly without all three factors,” David Kelly, leader of the ITC and former chief of the NHTSA told Automotive News Europe. “You have to have all three.” This is called a significant 3-way interaction effect.



The ITC has named three main technical factors that were all present in violent ruptures of Takata airbags linked to injuries and deaths.
PHOTO BY ADAM BARTLETT

7 Ways to Think More Critically

6. **When making decisions, ALWAYS consider more than one alternative and know/question the assumptions/constraints that are involved.**
7. **Continue to learn more and more about your processes, products, and people.**

Final Question

Question asked to Marilyn Vos Savant*

Say that I place a 25,000-mile-long metal band snugly around the earth. Assume a smooth spherical planet. Then I cut the band and splice another 50 feet to it, thus loosening it all around. Can I get my finger between the new-length band and the earth? Can I crawl under it?

Zan White, Elkins, W.Va.



* According to the Guinness Book of World Records, Marilyn Vos Savant has the highest IQ in the world, having an IQ at the $+8\sigma$ level.

Polling Question #3

Respond to the 25,000-mile band around the earth question by choosing one of the following:

1. I can crawl under the new band.
2. I can get my finger under the new band, but I will not be able to crawl under it.
3. I can neither crawl under the new band nor put my finger under the new band.

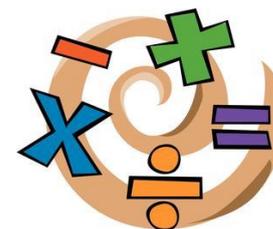
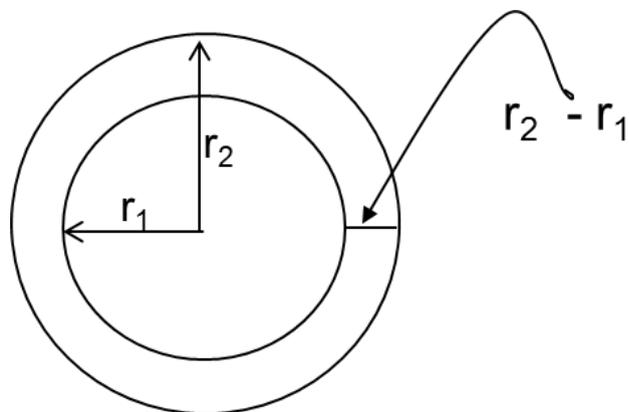
Vos Savant's Reply

“Amazingly, even the tallest basketball player could walk under that band, which would float about eight feet off the ground around the planet.

The circumference of the object is irrelevant. Adding 50 feet to any size band – one that wraps around a cantaloupe or the moon – will produce the same answer: The longer band will be about eight feet from the surface of the object it circles.”

vos Savant

The Math Behind the Question



$$C = \text{circumference} = 2 \pi r$$

r = radius

$$C \text{ (inner circle)} = 2 \pi r_1 \rightarrow r_1 = C/(2\pi)$$

$$C + 50 \text{ (outer circle)} = 2 \pi r_2 \rightarrow r_2 = (C + 50)/(2\pi)$$

$$r_2 - r_1 = (C + 50)/(2\pi) - C/(2\pi) = (C + 50 - C)/(2\pi) =$$

$$50/(2\pi) = 25/\pi \approx 7.96$$

A Follow-Up Question

Your reply to the question about the 25,000-mile band around the earth was so counterintuitive that I thought you had lost your edge. Then I did the math and learned that you were correct. Yet the answer still seems wrong to me. My question: ***Why do we cling to beliefs even after seeing facts that contradict them?***

- Steve Morris, Lincoln, Neb

Because people get freaked out by the notion of being wrong about anything. It makes them feel insecure. If you can be wrong about this or that, what about all the other stuff you think you know? And the more important the subject, the more unnerving the emotion. It's not too scary to be incorrect about a math concept, but how about the car you bought? Or the doctor you chose?

Your question goes to the heart of much unsound thinking. After we leave school, we tend to head down one of two roads:

- (1) We close our minds to new or different information while becoming more and more sure of ourselves; or
- (2) We watch, listen, and learn as we get older. The second road has way more bumps and curves, but it's also the path to wisdom.

- vos Savant

Thank You



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