Mathematical Thinking: Crash Course Statistics #2

Crash Course: Statistics
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Hi, I'm Adriene Hill. This is Crash Course Statistics. In the last video, we talked about why we care about statistics, how we use statistics, and Statistics is math.

So we thought we'd take a detour from the traditional curriculum to talk about how to think about numbers. Really, really big numbers. Really small numbers. And how to make sense of them.

We're also going talk about mathematical thinking. And fighter jets.

[Opening music]

Chances are, if you are watching this channel, and certainly if you are commenting below, you are literate. You understand language and how to use it. But are you equally comfortable with numbers?

I'm not talking about being able to calculate square roots in your head. Or instantly tell whether or not 17321 is prime or not. (It is. I looked it up.)
Numeracy is about being able to wrap your head around what it means when politicians talk about a one-point-five-trillion-dollar budget hole. It's about getting a handle on how much you should really lose sleep over the chance of an Ebola outbreak. And how to compare that risk to the chance of being killed by a terrorist. Or a snake bite. Or dying from an opioid overdose. And what those comparisons might tell us about the time and resources we spend trying to address those problems.

Mathematical thinking is about seeing the world in a different way, which means sometimes seeing beyond our intuition or gut feeling. Because it turns out most of our guts are good at digesting food and pretty bad at math. Infants less than a year old can discern between three objects. I am much more advanced than an infant and can pretty easily comprehend the difference in one and a hundred. Even the difference between a hundred and a thousand or maybe even ten thousand.

For most of us, once numbers get really big, we lose our ability to have any intuitive sense of them. The distinction between a million and a billion and a trillion is really hard to visualize. There are 100 trillion bacteria in each of our bodies and non-mathematical guts. 100 trillion. There are an estimated 10 quintillion insects that are alive right now. And an estimated 300-sextillion stars in the universe.

So how do you even begin to think about those big numbers and what they mean? Let's go to the Thought Bubble.

Take a minute to visualize the difference between one and one hundred and one thousand and a hundred thousand and a million. That's a lot of dots, a whole lot of dots.

There are other good ways to try to make sense of big numbers. You can try to put the number in context. The US debt is in the neighborhood of 20 trillion dollars. About 323 million people live in the US. So, the debt owed for each person is about sixty-two thousand and five hundred dollars.

You can turn a big number into a unit of measurement you are more comfortable with. The Kola Superdeep Borehole, which is the deepest artificial point on earth is 40,230 ft deep. I have no idea how deep that is. Until you tell me that it's 7 and a half miles down. And I can start to picture it.

You can have reference points for big numbers, ready to go. There are about 100-thousand words in a 400 page novel. About 46-thousand people show up to Dodgers games in Los Angeles. I can roughly visualize that. A million people taking to the streets to protest might be easier to think of as 21 Dodger Stadium's worth of people. Or 14 and a half crowds for a Real Madrid match.

Time can help us go even bigger. A million seconds is a little less than 12 days. What about a billion seconds? Do you think you are a billion seconds old? Are you older than 32? It takes 32 YEARS for a billion seconds to pass. And what about a trillion seconds? Think you or I will be alive after a trillion seconds passes?

Sorry to break it to you. But no. We will not. Even if you are destined to be the Guinness Book of World Records oldest woman. There is a 100% chance, barring massive medical breakthroughs that you will be dead. It takes 32-thousand years for a trillion seconds to tick by.

Thanks Thought Bubble.

A quick note about scientific notation. Scientific notation can be really helpful for calculating with big numbers, but not necessarily helpful for understanding them. Without context, exponents can be non-intuitive if that's a word in their own way.

10 to the 39th and 10 to the 32nd sound like they might be close. But 10 to the 39th is 10 million times larger than 10 to the 32nd. We're not going to run the dots on that one.

There are about 7.6 billion people on earth. 7.6 billion. Understanding the sheer number of people out there in the world, can help us make sense
of the commonness of coincidences or improbable events. Some statisticians call it the "law of truly large numbers." The idea here is that with a large enough group, or sample, unlikely things are completely likely to happen.

Consider this example from statistician David Hand. On September 6th, 2009, the Bulgarian lottery randomly selected as the winning numbers 4, 15, 23, 24, 35, 42. And then, four days later, on September 10th, the Bulgarian lottery randomly selected new winning numbers: 4, 15, 23, 24, 35, and 42. Exactly the same numbers. People freaked out. Bulgaria's sports minister ordered an investigation. Was it fraud? Something else? Hand says calm down. It's just coincidence.

He lays out the math to prove it, but part of the argument here is the law of truly large numbers. If you consider the number of lotto drawings, every week, around the world, over years and years, "it would be amazing" he wrote, "if draws did not occasionally repeat."

Speaking of those incredibly unlikely things, we need to talk about the flip side of incredibly big numbers - the incredibly small numbers that can also be hard to comprehend. Take the likelihood of winning a Mega Millions jackpot in the US. Right now it's about one in 302.6 million. The probability that you'd win the jackpot is 0.000-000-003-305.

Let's put the teeny-tiny chance of that happening in some perspective 302.6 million is the number of seconds in more than 9 and a half years. So, to borrow here from a very funny post by Tim Urban on Wait But Why that's like knowing that a hedgehog will sneeze once in the next 9 and a half years and betting on the exact second during those nine and a half years that the hedgehog will need a tissue. I'm going with May 2nd, 2:23 and 33 seconds PM, 2021.

Our inability to judge small numbers does more than just cause us to misjudge our chances of winning the lottery. It causes us to worry about the wrong things. To fear the wrong things. Take your chance of dying from Ebola. If you live in the US, the chance that you'll be killed by Ebola in any given year is pretty close to your chance of winning the mega millions lottery. One in 309.6 million. It is, among

the very, very least likely ways anybody living in the US will die in a year.

Though you are, by some accounts, less likely to be killed by a terrorist attack in the US committed by a refugee. In a 2016 study, researchers calculated that at one in 3.64 Billion chance in the US in a given year. And you far more likely to be die in dozens of other ways.

There is a one in 6 million chance someone living in the US will be killed in a given year by bee sting. A one in 708-thousand chance that they'll die falling from a ladder. A one in 538 chance they'll die in a given year from cancer. And, not a big cause of death, but did you know people die in sand holes that they or their friends have dug out at the beach. They crawl in. Looking for a little time in the sand hole. And woosh. The hole suddenly collapses and they are buried. Stay out of sand holes.

I'm going to stop because it's stressing me out. The point here is that it's worth taking the time to think through small numbers. Cause they can help you figure out what's actually worth worrying about. And what isn't. What you might want to act on and what you might want society to take more and less seriously.

My personal take away is that I'd be way better off spending more time exercising and less time looking around obsessively for poisonous snakes. Cause the annual odds of dying from a snake bite in the US are only about one in 34 million, but the odds of dying from heart disease in any given year are one in 534.

Thinking mathematically isn't just about understanding numbers better.
It's about asking important questions about the world around us. And letting numbers illuminate those questions. One of my favorite examples mathematical thinking is the story of Abraham Wald and the missing
bullet holes. Hat tip here to mathematician Jordan Ellenberg for highlighting the story.

Let's go to the News Desk.

World War II: Manhattan. A group of statisticians and mathematicians are hard at work trying to protect American fighter pilots. Their task: trying to figure out how to best armor planes without making them too heavy
so our heroes to outrun and outwit the enemy.

In an effort to figure out how to best protect our planes, the statisticians pour over data of the planes that returned from fighting, looking at where they took damage. Where the bullet holes were.

That data showed there were more bullet holes in the fuselage and fuel system and not as many in the engines. So how do we save our American heroes?

The exceptional statistician Abraham Wald studied the data and came back with the advice that surprised everyone to put the armor where the bullet holes weren't. Over the engines. Wald realized the bullet holes should have been more evenly distributed over the planes. If fewer planes were returning with holes in the engines, that meant those planes weren't returning home.

Wald has the exceptional realization the data wasn't a random sample of all planes. It only represented the planes that returned. He suggested the military add armor to engines. American lives were saved!

Not all mathematical thinking is going to help you save lives. But it will help you make better decisions- Mathematical thinking can help you see past
coincidence. It can help you judge risks. It can help you see the broader relationships in the world. Thinking mathematically gives us something to go on other than our guts, and their trillions of bacteria.

Thanks for watching. I'll see you again next time.

Crash Course Statistics is filmed in the Chad and Stacy Emigholz Studio in Indianapolis, Indiana, and it's made by all of these nice people. Our animation team is Thought Cafe.

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