## Stochastic Deviation

"We interrupt this news broadcast for a live report from Madrid, Spain, where something truly sensational is unfolding." The breaking news was showing on most TV screens around the globe. "It's captured the attention of statisticians worldwide—and also that of all of us who cling to impossible dreams." The newscaster flashed a shrewd smile. "Over to you, Armando in Madrid."

"Yes!" Armando took over. "I'm standing here, in the streets of Madrid, in front of what started as a simple bet between two people, and has now turned into a massive gambling frenzy." The camera turned from Armando to show a crowd of people surrounding a central figure who was throwing a small object up in the air. "What's happening? It's a coin toss! A heads or tails game—but with a bizarre twist: tails refuse to show up!" The camera zoomed in on Armando who continued with an incredulous expression, "after around 1800 flips, the coin has landed heads up, every, single, time! This has by now become a global sensation—it is baffling people everywhere!"

A different shot showed a speeding taxi cab coming to a halt. "This," Armando continued, "must be the world-

renowned probabilist we've been expecting, Dr. Manuel. I'm going to ask him what he makes of all this."

The camera showed Armando make his way through the crowd towards the man who had hurried from the car to the center of attention.

"Dr. Manuel?" Armando thrust the microphone toward the man's face.

"Si?"

"So. What do you think? What do you make of this, Doctor? I see you're inspecting the coin. Is it loaded?"

"Hmm. I was convinced it must be," said the expert, looking baffled, "but I find nothing at all wrong with this coin. It is perfectly fine! The way that it's tossed and the coin's composition make it equally likely to land heads or tails. This should not at all happen."

"Yet here we are," Armando definitely wanted some better explanation, "with heads winning every time!"

"It must be… just an incredibly unlikely coincidence. Any moment now it must land tails."

"Do you really think so?"

"Yes, of course. I am certain! Each flip has a fifty-fifty chance of landing heads or tails. The odds of getting 100 heads in a row are astronomically small."

"But we are now closing in on 2000 heads in a row!"

"Yes," Manuel repeated, "and this is so improbable it's practically impossible.” He absentmindedly shook his head. “Impossible I say!"

"Until today,” rhymed Armando. “And people here are now betting on how many more times heads will come up. What do you make of that?"

"Well, it’s not surprising. We’re dealing with the gambler’s fallacy. The chance of heads continuing to come up is very small, so it would seem a safe bet to bet on tails. If I wasn't sure every toss had a fifty-fifty chance, I would also bet that tails would come up."

"Not the case!” Armando said with a conceited smile, "no one here is betting on tails!"

Manuel looked about to say something, but stopped himself, so Armando continued, "they’re all betting on heads to keep showing up. And they’re winning. A lot!"

"…!" Dr Manuel looked perplexed, muttered something about ‘inverse fallacies’ and scratched his head.

"It seems," Armando said, "the gamblers believe that, since heads have shown up nearly 2000 times already, it is actually more likely that heads will show up yet again."

Manuel gave a nervous chuckle. "That’s completely illogical! There’s no reason heads should keep coming up just because it has before."

"Of course. But it does seem as if logic has taken a sidestep from reality here. In fact, many people are starting to doubt logic itself. Doubt it as a philosophy! They now call it a 'theory'—a 'theory' that has been proven wrong. They are saying that other, irrational, inexplicable, forces must be at play. Even the betting agencies are pulling out—they are running out of money! The odds for tails are now astronomical compared to heads. This of course defies both logic and probability."

"Look," said Manuel, "the probability is what it is. There is a chance that heads could come up 2000 times in a row, even though it's so small that no one ever thought it would, or even could, happen. One toss is fifty-fifty, that is, there is a 50% chance that tails will come up and a 50% chance that heads will."

Armando sensed a lecture coming on and motioned for the cameraman to get a better and closer angle of the expert.

"If you toss it twice and want to know what the chance is for two heads, you will need to multiply the chances of each toss—that is 50% times 50%, or half of 50%, which is 25%. There is a 25% chance, or one in four, of heads coming up twice. For every extra toss, the chance for *all* heads gets halved—one in eight, one in sixteen and so on. It's exponential! You can express the chance as one in two to the power of the number of tosses minus one."

Armando wasn't sure he followed the math, but he kept a straight face and let Manuel continue.

"Now, it follows that the chance for heads to turn up 2000 times in a row is about one in two to the power of two thousand." Manuel pulled out a calculator and did a quick calculation. "That is a ridiculously large number! More than 600 digits long! For comparison, the number of atoms in the whole universe is estimated to be around two to the power of just two hundred and seventy-five..." An expression of utter disbelief came over his face. “We’re in googology territory…”

Armando didn't really look like he appreciated the magnitude of the numbers involved. And he countered: “But wait a minute! It’s said that given enough time, a monkey hitting random keys on a keyboard could create the works of Shakespeare. Surely, then, a streak of 2000 heads is no big feat!”

The doctor actually groaned. “That theorem has been so utterly disproved it’s not funny. Getting a monkey to write just the six words ‘to be, or not to be’ would take about one quindecillion times the current age of our universe.”

Armando looked a bit long-faced. "Okay, well, then, given that what is happening here is, indeed, happening, doesn’t that put the entire field of probability to the test? Isn’t it a bit of a setback for you as a probabilist, seeing people bet thousands of dollars on the illogical choice of heads, just to win a few bucks?"

Just as Dr. Manuel opened his mouth to respond, somebody yelled "heads up!" and a coin flew past, tossed high in the air by an eager gambler. The crowd held their breath as it

twirled and shimmered in the sunlight... and landed... perfectly balanced, on its edge.

There was a moment of stunned silence, and then a voice in the back yelled, “I bet five grand it stays that way!” The crowd erupted in laughter, and Manuel resignedly sighed. Then the coin fell to its side, showing heads up.

Dr. Manuel had nothing more to say. He felt eerily exhausted, really just wanted to leave and go home. After a few more coin tosses he could be seen getting out his checkbook and bet his entire savings on the next toss being heads. It was, but for whatever reason, he didn’t feel much richer for it...

"Well, Doctor," Armando ended his interview, "even though this whole situation doesn’t make any *cents*, at least you can say you came out a *head*.”

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