

## Could Monkeys Really Type All of Shakespeare?



**Not in this universe, a new study concludes.**

Science doesn't usually tolerate frivolity, but the infinite monkey theorem enjoys an exception. The question it poses is thoroughly outlandish: Could an infinite number of monkeys, each given an infinite amount of time to peck away at a typewriter (stocked with an infinite supply of paper, presumably) eventually produce, by pure chance, the complete works of William Shakespeare?

The problem was first described in a 1913 paper by the French mathematician Émile Borel, a pioneer of probability theory. As modernity opened new scientific fronts, approaches to the theorem also evolved. Today, the problem pulls in computer science and astrophysics, among other disciplines.

A new paper by Stephen Woodcock, a mathematician at the University of Technology Sydney, suggests that those efforts may have been for naught: It concludes that there is simply not enough time until the universe expires for a defined number of hypothetical primates to produce a faithful reproduction of "Curious George," let alone "King Lear." Don't worry, scientists believe that we still have googol years —  $10^{100}$ , or 1 followed by 100 zeros — until the lights go out. But when the end does come, the typing monkeys will have made no more progress than their counterparts at the Paignton Zoo, according to Dr. Woodcock.

"It's not happening," Dr. Woodcock said in an interview. The odds of a monkey typing out the first word of Hamlet's famous "To be or not to be" soliloquy on a 30-key keyboard was 1 in 900, he said. The chances of a monkey spelling out "bananas" are "approximately 1 in 22 billion," Dr. Woodcock said.

Even if the life span of the universe were extended billions of times, the monkeys would still not accomplish the task, the researchers concluded. Their paper calls the infinite monkey theorem "misleading" in its fundamental assumptions. It is a fitting conclusion, perhaps, for a moment when human ingenuity seems to be crashing hard against natural constraints.

Low as the chances are of a monkey spelling out "bananas," they are still "an order of magnitude which is in the realm of our universe," Dr. Woodcock said. Not so with longer material such as the children's classic "Curious George" by Margret Rey and H.A. Rey, which contains about 1,800 words. The chances of a monkey replicating that book are 1 in  $10^{15000}$  (a 1 followed by 15,000 zeros). And, at nearly 836,000 words, the collected plays of Shakespeare are about 464 times longer than "Curious George."

"If we replaced every atom in the universe with a universe the size of ours, it would still be orders of magnitude away from making the monkey typing likely to succeed," Dr. Woodcock said.

This conclusion circles back to the French mathematician Borel, who took an unlikely turn into politics, eventually fighting against the Nazis as part of the French Resistance. It was during the war that he introduced an elegant and intuitive law that now bears his name, and which states: "Events with a sufficiently small probability never occur." That is where Dr. Woodcock lands, too.

There is no free lunch, so to speak, said Eric Werner, a research scientist who runs the Oxford Advanced Research Foundation. In a 1994 paper about ants, Dr. Werner laid out a guiding principle that, in his view, applies equally well to typing monkeys and today's language-learning models: "Complex structures can only be generated by more complex structures." Lacking constant curation, the result will be a procession of incoherent letters or what has come to be known as "A.I. slop."

A monkey will never understand Hamlet's angst or Falstaff's bawdy humor. But the limits of A.I. cognition are less clear. "The big question in the industry is when or if A.I. will understand what it is writing," Mr. Anderson, an American programmer, said. "Once that happens, will A.I. be able to surpass Shakespeare in artistic merit and create something as unique as Shakespeare created?"

And when that day comes, "Do we become the monkeys to the A.I.?"

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