The Future is not Determined

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1 Introduction

Philosophers and religious thinkers down through the ages have asked, Is the future determined or knowable? People have paid huge sums to sages and psychics for answers. Prophets have claimed divine revelations. Religions have described sweeping predictions of apocalypses and judgment days.

In this essay I will discuss the predictability of the future based upon the extremely well tested theory of quantum mechanics, with an illustration from my doctoral experiment.

Under Newton's laws of motion, if the location and speed of every particle in the Universe were known to extreme precision, then the motion of all those particles could be calculated exactly in the future.

Newton's laws seemed reasonable, because the motions of the planets can be predicted with high accuracy.

But then quantum mechanics was discovered in the 1920s, with Heisenberg's uncertaincy principle, and determinism was gone forever.

2 The kaon or K-meson

For my Ph.D. experiment at Princeton University, performed at the Brookhaven National Laboratory's AGS accelerator, I and my colleagues did what is conceptually a simple experiment, but one with profound implications for the meaning of reality.

We studied 3 million reactions of charged kaons, K^+ and its antiparticle, K^-.

Kaons are just as real as protons, electrons, photons (particles of light), proteins, DNA, stars, black holes, and apple pie, except that kaons are unstable (radioactive) and exist for only a few billionths of a second. You'll probably never meet one.

A K^+ is a composite particle consisting of an up quark and an antistrange quark. The kaon is unstable because the strange quark is unstable.

Thousands of kaons were produced when the accelerator's proton beam hit a target

of ordinary matter. The kaons flew out in all directions, some passing into our particle detector. We could count them one by one–they were real!

Each kaon has a mass of 493.677 MeV/c^2, which is slightly less than half the mass of a proton, but much heavier than an electron.

EVERY KAON IS EXACTLY IDENTICAL TO EVERY OTHER.

Kaons are spherically symmetric (round like a ball), unlike protons, electrons and photons, which have spin.

Thus a kaon is a really, really simple object to think about.

Because a kaon has so much energy, it can split up into a number of lighter particles–pions, muons, electrons, and neutrinos.

The average lifetime of a kaon is only $1.238x10^{-8} = 0.00000001238$ seconds, but this is many times longer than computer clock times. The kaons lasted plenty long enough to travel from the accelerator into our detector before they disintegrated.

Every kaon, although identical, did not always split up at the same time, nor in the same way. The permitted decay modes are:

$K^+ \rightarrow \mu^+\nu_u \quad 63.55\%$

$K^+ \rightarrow \pi^+\pi^0 \quad 20.66\%$

$K^+ \rightarrow \pi^+\pi^+\pi^- \quad 5.59\%$

$K^+ \rightarrow \pi^+\pi^0\pi^0 \quad 1.761\%$

$K^+ \rightarrow \pi^0 e^+\nu_e \quad 5.07\%$

$K^+ \rightarrow \pi^0\mu^+\nu_u \quad 3.353\%$

Uncharged particles are difficult to detect, so we decided to study only the decay into 3 charged pions. We measured the paths and speeds of all three pions, using state-of-the-art (for 1967, at least) computers.

The results were:

• The K^+ behaved exactly oppositely to its antiparticle, K^-. The masses, lifetimes, branching ratios, and the speed distributions of the 3 pions were all the same.

• The probabilities were *completely random*: decay probability, decay mode, directions and speeds of the 3 pions.

• Because the kaon is round, the decay particles flew off randomly in all directions.

For comparison, I had to generate pseudodata on the computer, using a random number generator to simulate each random aspect.

I had great difficulty devising a deterministic mathematical algorithm which produced good pseudorandom numbers.

Electronic slot machines in casinos have random number generators. To get really good random numbers, physicists use quantum mechanical processes!

3 Quantum mechanics describes all small things

All small objects such as protons, electrons, photons, kaons, atoms, molecules, crystals and materials, chemical reactions, DNA and transistors are described by quantum mechanics.

Quantum mechanics is the most well tested theory of physics, and has passed thousands of experiments.

The *Standard Model* of the elementary particles is nearly complete.

Some objects, such as the hydrogen atom, have been calculated to parts per billion accuracy.

Other objects, such as protons, neutrons and atomic nuclei, are only partially understood. Complicated molecules such as proteins and DNA are bitches to calculate, requiring supercomputers.

Composite structures such as COVID-19 viruses and human host cells all obey quantum mechanics, but how does that virus really work?

4 The wave function Ψ and randomness

Traditionally the Greek letter Ψ denotes the quantum mechanical wave function. Particles such as electrons, photons and kaons are not described as point particles as Newton did, but rather as waves. You already know about lots of kinds of waves such as sound, radio and water waves. The same sort of wave equations apply in quantum mechanics.

The absolute value squared of Ψ gives the probability that something happens:

$$\text{probability} = |\Psi|^2$$

Compute Ψ, and you know the probabilities that the system will do various things.

THE FUTURE IS NOT DETERMINED.
QUANTUM MECHANICS ONLY PREDICTS PROBABILITIES.

Thus for a K^+, the probability that it splits up into $\pi^+\pi^+\pi^-$ is 5.59%.

5 How is the randomness produced?

Nobody knows. In my experiment, only one thing happened with each kaon, not all possibilities.

Physicists have various interpretations of the meaning of the wave function. One theory–the multiverse theory–is that all possibilities happen, and that the Universe splits into all possible universes!

I find the multiverse theory too bizarre to believe.

All I know is that quantum events are very, very random, with no apparent meaning nor purpose whatsoever.

Of course some people might believe that God chooses the random numbers, and determines what will happen according to his plan. I respect my religious friends' opinions, but hold no such beliefs myself.

I believe that the Universe is meaningless, but that we humans can create the meaning for ourselves.

6 The macroscopic world is predictable, more or less

I am typing this essay with 100% certainty that hitting the X key will cause an X to appear on the screen. If I drink plenty of coffee and proofread the manuscript several times, I might even get all the spelling right. My brain can get things correct, except for the doctor's appointment I forgot yesterday!

In the macroscopic world we usually see order, not chaos, except when we step into a casino, read the hurricane report, watch wildfires in California and Oregon, and follow politics.

The President "by chance" caught the virus!

Still, though, the macroscopic laws of physics (Newton, Maxwell and Einstein), are deterministic. The Boeing 737 Max crashed because of a design flaw in a safety computer. The unsinkable Titanic sank because it crashed into a homungous iceberg at full throttle. WW2 started because Germany attacked Poland, and Japan attacked Pearl Harbor.

All these events did not involve chance, and might have been preventable by wise human forethought. We are not entirely at the mercy of quantum mechanical fluctuations.

7 Is there such a thing as Free Will?

Certainly the brain is a computer subject to the laws of quantum mechanics. With intense concentration we can think deterministically, e.g., solve complicated math problems. In practice our thoughts often seem to flit about a bit randomly, caused perhaps by the random release of neurotransmitter between neurons. When I stuck micro-electrodes into the brains of cats, I detected quite a bit of noise.

Sometimes I wake up in the morning not quite sure what I'm going to do, and end up writing an essay like this one!

I believe that free will requires the following:

• Define a reasonable question. For instance, speculating how many angels can dance on the head of a pin is ill-defined. But asking, Can Vitamin C prevent cancer can be studied.

• Gather relevant information. When I was at universities, I spent hours in libraries reading heavy journals. Now I can find almost everything online with a Google search.

Google will also find all kinds of scams. Read my book, *The Art of the Scam*, available on Amazon Kindle. The mark of a true scholar is the ability to distinguish between good information, uncertain data, and fraud.

• Make logical connections between observations and information to form a hypothesis.

• Do additional experiments and gather more information to confirm or reject the hypothesis. Hypotheses should be discussed with other scholars.

• Well-accepted hypotheses are called theories, not facts, because additional information might disprove those theories.

Thus I believe that Homo sapiens, and perhaps certain other species, have free will, although regretably some people fail to exercise it.

8 The Theory of Evolution

Charles Darwin's great theory depends on chance:

1. The father and mother pass their genes on to their offspring randomly. I've watched sperm under a microscope swimming frantically and randomly to be first to reach the egg!

2. The fittest organisms, on average, survive more of the time.

A man and a woman each have 46 chromosomes. They each pass 23 chromosomes at random to their offspring in an egg and a sperm. There are thus:

2^{46} = 70,368,744,180,000 possible offspring.

This is far more babies than there are people on Earth!

Most of these offspring are ordinary, probably carrying a number of detrimental but not fatal characteristics, and having some bad recessive genes. Some offspring are inferior and fail to reproduce. A few offspring are superior, and give birth to more superior offspring which are better able to survive in new challenging circumstances.

Evolution has no intelligence whatsoever; the most fit creature might by accident fall into a hole, break its neck, and be eaten by lions!

One individual can change the course of history. What if Moses, Alexander the Great, Julius Caesar, Jesus, Muhammed, Newton, Abraham Lincoln, Edison, Lenin, Einstein, Hitler, or Trump had not been born?

One coronavirus, perhaps living in a bat, had a mutation of its RNA (a quantum mechanical event) and jumped to humans. We have witnessed a new species evolve before our eyes! This unusually virulant virus quickly spread from Wuhan, China throughout the world in a few months, now killing over 1 million people! Fortunately for us, COVID-19 kills only about 2% of its victims–mostly old people. The human race will survive this pandemic.

The 1918 Spanish flu was far more virulent, killing 50 million young adults and children.

According the the Theory of Evolution, new pandemics such as HIV/AIDS, malaria, SARS, various strains of the flu, ebula, measles, tuberculosis, polio, and bubonic plague will always keep arising and infecting the billions of humans living densely in cities, and traveling all around in airplanes–the perfect storm.

The next pandemic might be far worse. Have humans evolved enough to stop it???

Is evolution cruel? Yes, sometimes. Is evolution immoral? Morality does not apply to a mindless mechanism such as COVID-19. Does evolution always lead to progress? No, not necessarily; a meteorite by chance hit the Earth and wiped out the highly successful dinosaurs, but opened the way for mammals.

We Homo sapiens think that we are the pinnacle of evolution. But we could destroy most all life in an all-out nuclear war! Perhaps anthropogenic global warming is already causing the next mass extinction of species. Another meteorite or catastrophe could wipe out human civilization.

Yet through concerted effort by the wisest minds through democratic discussions, we might just possibly make the undetermined future better.