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What is Objective Probability?

Recall that one of Seaborgium's isotopes, ^{265}Sg, has a half-life of 8.9 seconds. That means that if you take a particle of ^{265}Sg and wait 8.9 seconds, the probability that it will decay is 50%.

When we speak of probability in this context, we are talking about **objective probability**.

To say that ^{265}Sg has a half-life of 8.9 seconds is to describe a feature of the external world, rather than an aspect of anyone's psychology.

But what feature of the world is that?

In this section we will try to answer that question.

(A note about terminology: philosophers sometimes refer to objective probability as "objective chance", or simply "chance". I will occasionally follow that practice below.)

Frequentism

We will start by considering an answer that is tempting, but ultimately unsatisfactory.

According to **frequentism**, what it means for a particle of ^{265}Sg to have a 50% probability of decaying within the next 8.9 seconds is for the *frequency* of decay of ^{265}Sg particles to be 50%. In other words, it means that 50% of the ^{265}Sg that exist at a given time decay within 8.9 seconds.

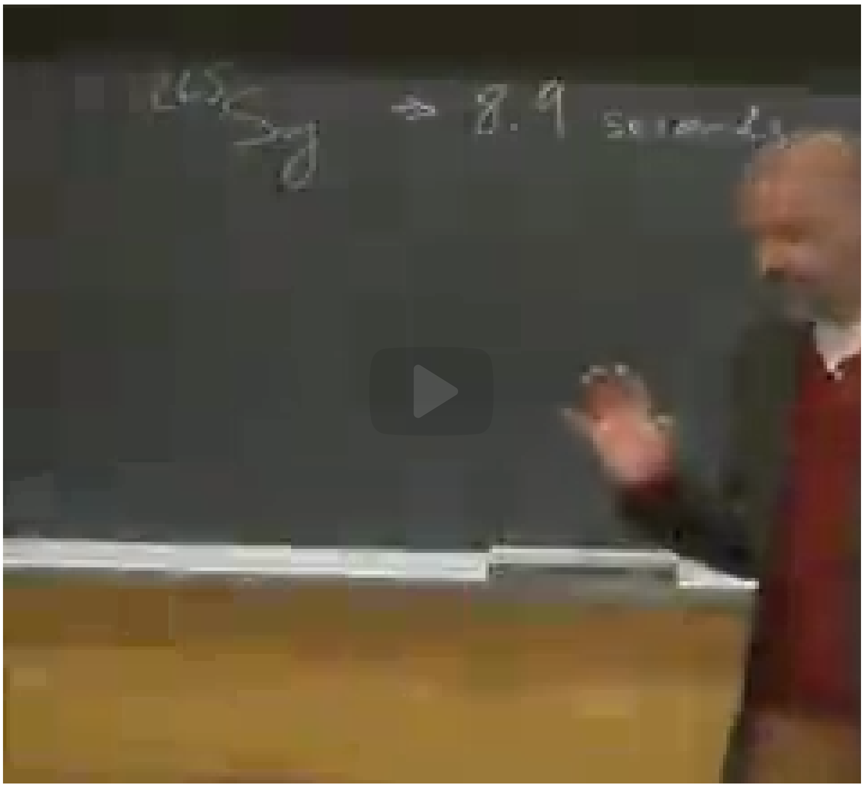
Unfortunately, frequentism cannot be correct.

To see this, think of a "coin toss" as the result of observing a particle of ^{265}Sg for 8.9 seconds. If the particle decays within that period, our "coin" is said to have landed Heads; otherwise it is said to have landed Tails. Now imagine a situation in which only three particles of ^{265}Sg ever exist and in which the ensuing "coin tosses" yield: Heads, Heads, Tails. Before any of the "tosses" took place, what was the chance that they would land Heads? The answer ought to be 1/2. But frequentism entails the mistaken conclusion that the answer is 2/3.

A slight improvement on straight frequentism is what is sometimes called “hypothetical frequentism”. The basic idea is this: if we had performed a sufficient number of "coin tosses'', we would have gotten Heads 50% of the time. (I will set aside the question of how many tosses would count as sufficient'').

Unfortunately, hypothetical frequentism can't be right either: it is simply not true that a fair coin -- a coin with a 50% chance of landing Heads -- must land Heads 50% of the time in the long run. It is perfectly possible, for example, for such a coin to land Heads on every single toss. Such an outcome would be extremely unlikely, to be sure. But it is certainly *possible*; that just follows from the fact that the coin has a 50% chance of landing Heads on any given toss.

Video Review: Frequentism



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So although this recipe would give us

a very good way of guessing what the probabilities are,

it wouldn't be a good way of defining

what the probabilities are because the definition would

fail in these very unlikely cases.

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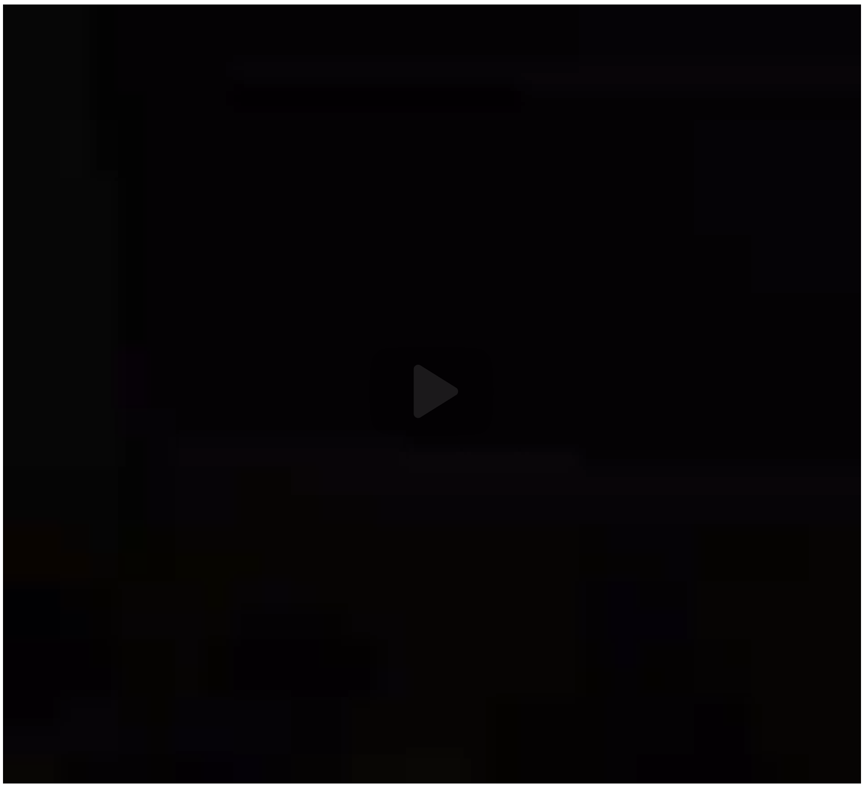
The fact that a coin is fair does not guarantee that it will land Heads 50% of the time. But a weaker statement is true. It is true that if the coin were tossed a sufficiently large number of times, then it would *with very high probability* land Heads approximately 50% of the time.

A rigorous version of this principle is known as the **Law of Large Numbers**, and is a theorem of probability theory. It is because of this law that casino owners can feel confident that they will, in the long run, make a profit. A particular table, or a particular slot machine, will have bad nights now and then. But as long as the casino is visited by enough players over a sufficiently lengthy period of time, it is extremely probable that the casino's gains will outweigh its losses.

The Law of Large Numbers tells us that frequentism has a grain of truth, since it entails that observed frequencies can be a good guide to probabilities. But the Law of Large Numbers also tells us what frequentism got wrong. Frequencies are not necessarily a *perfect* guide to probabilities. The Law tells us that if the objective probability of a coin landing Heads is 50%, then it is *very probable* that the coin will, in the long run, land Heads approximately 50% of the time. But that means it is *possible* that it won't. And if frequencies aren't a perfect *guide* to probabilities, they certainly aren't *identical* to probabilities.

Video Review: The Law of Large Numbers



use the law of large numbers to be

certain to a large enough extent that we're going

to make money in our casino.

And of course, it could fail, but it's very, very probable

that it will not.

It goes without saying that here we haven't defined probability,

since we're using the notion of probability in the definition.

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Problem 1

1/1 point (ungraded)

Here is a more precise statement of the Law of Large Numbers,

> **Law of Large Numbers**
> Suppose that events of type T have a probability of p of resulting in outcome O. Then, for any real numbers ϵ and δ larger than zero, there is an N such that the following will be true with a probability of at least $1 - \epsilon$:
>
> If $M > N$ events of type T occur, the proportion of them that result in outcome O will be $p \pm \delta$ ("$\pm$" means "plus or minus").

Suppose there is a casino with many slot machines. Each time a customer uses one of the slot machines, the casino has a 49% chance of losing a dollar and a 51% chance of winning a dollar.

Is the following true or false?

> If the casino has enough customers at the slot machines, it is at least 99.99% likely to end up with a profit of at least a million dollars.

- (•) True
- ( ) False

✔

Explanation

Set $\epsilon = 0.0001$. Set δ to be some number smaller than 0.01; say $\delta = 0.005$. It follows from the Law of Large Numbers that there is an N such that the following will true with probability of at least $1 - \epsilon = 0.9999$: If the slot machines are used $M > N$ times, then the proportion of them that result in a win for the casino will be 0.51 ± 0.005. So, if the machine is played M times, there is probability 0.9999, that the casino wins at least 50.5% of the time, and therefore ends up with a profit of at least $M \cdot 0.505 \cdot \$1 - M \cdot 0.495 \cdot \$1 = \$\left(M \cdot 0.01\right)$ (which will be more than a million dollars, for large enough M).

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Answers are displayed within the problem

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