

Think fast – you're a physics genius

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Some snap decisions are surprisingly smart. That's because a little scientist inside your head takes care of the mathematics.

THE idiocy of humankind is a topic as entertaining as it is inexhaustible. Among our many inabilities, one of the most pathetic is our ineptitude in juggling probabilities.

Suppose, for example, that you have an ordinary six-sided die with four green faces and two red ones. Your task is to choose one of the sequences below, then roll the die 20 times. If your selection turns up, you will win \$25. Which one will maximise your chances of winning?

- (1) RGRRR
- (2) GRGRRR
- (3) GRRRR

A majority of people choose (2) over (1). But that cannot be right: sequence (2) contains (1), so (2) must be less likely than (1).

Psychologists Daniel Kahneman and Amos Tversky have shown that this and many other disastrous statistical mistakes are endemic in human thought. In his fascinating recent book *Thinking, Fast and Slow*, Kahneman explains this slip as follows. When you look at the three sequences, you see that the mix of green and red in (2) is closer to the proportions of green and red on the die itself. A "representativeness heuristic" programmed into your mind tells you that representative choices are good choices; you therefore select (2).

You are not the helpless victim of the representativeness heuristic, however. You can also think your way carefully through the problem and see that although sequence (2) is more representative than (1), it is less probable.

Why, then, do so many people make the wrong choice? Because thinking using the representativeness heuristic is fast, effortless and automatic, whereas thinking logically is slow, relatively difficult and requires determination and self-control. Everyone feels the pull of choice (2), but only those who push themselves to double-check will work out the correct answer.

More generally, Kahneman endorses the influential psychological hypothesis that there are two kinds of systems in the mind. System 1, where the representativeness heuristic makes its home, is one of instinct or intuition. It is the mental ninja with lightning reflexes, using a limited amount of information to get to conclusions in a fast and shallow way – worth it in dangerous situations when slowness equals death. System 2 is the professor. It thinks deeply and theoretically, taking everything into account and producing much mental pain – worth it when avoiding error is what matters most.

Missing from Kahneman's picture is, I think, an important feature of the mental landscape. Certain System 1 processes are profoundly professorial: although fast and effortless like all their kind, they are also deep, theoretical and sensitive to the entire gamut of relevant information. What's more, they have played a crucial role in some of the most important scientific discoveries, a role that has gone unnoticed because of the very effortlessness of the path from premise to conclusion.

Go back to that two-coloured die. When choosing your sequence, you take it for granted that when you roll the die, each face is equally likely to land uppermost, so that green is twice as probable as red. Why are you so sure?

You are not just guessing. If I told you that the die was loaded, or that one face was sticky, you would abandon your judgement of equal likelihood. But if I told you that, before each throw, the die is rotated so that one of the red faces is uppermost, you would judge that this makes no difference to the statistics provided that the die is given a sufficiently good shake. You seem to know quite a bit about what matters to the outcome and what does not.

Are you making these judgements based on statistical experiment? No, not experiment, but theory. Somehow we all have a subtle understanding of the mechanics of tumbling dice, one rich enough to see what will and will not make a difference to the results. This understanding is also fast, effortless and largely unconscious: you hear the question and you grasp the answer, without knowingly doing any physics or mathematics.

It is System 1 that does the thinking. Nestled somewhere among all those crude, often erroneous heuristics highlighted by Kahneman is a physics genius who takes care of the mathematics for you and hands you the answer without your having to break sweat or even add two and two together. And so the answer seems obvious to you – but you can't explain how you reached it. Nor should you try; you will soon find out that the physics is rather daunting. Leave it to your instinctive genius, to the little scientist inside your head.

Here is another example of the little scientist's handiwork. Six balls are bouncing around in a box. Four are green and two are red. There is a hole in the side of the box and eventually, one of the balls will fly out. How likely is it to be a red ball? The chances are, of course, one in three. What if the bouncing always begins with one of the red balls in the top left corner of the box? As long as the balls bounce for a while, it makes no difference: the odds of a red one coming out are one in three.

Try to show that the top left starting position for one red ball makes no difference to the probability, and you will find your System 2 struggling with an extremely difficult physics problem, one that very few people could solve. Leave it to System 1, however, and the answer just pops into your head.

If System 1 did not have this ability, the history of science might have been different. In 1859, the physicist James Clerk Maxwell put forward a hypothesis about the probability distribution of gas-molecule velocities. Later known as the Maxwell-Boltzmann distribution, it became the foundation of the new science of statistical physics.

Maxwell had no data on molecular velocity; in fact, the very assumption that gases consisted of fast-moving molecules was extremely controversial. He derived his hypothesis not from empirical results, but from pure thought. He wrote down some statistical postulates about molecules that seemed plausible, thinking about them as though they were balls bouncing around in a box, and then used his mathematical skills to derive their velocity distribution.

The success of this enterprise hinged on these "plausible" postulates. Where did they come from? From System 1: they are precisely the postulates that you used to answer the question about the top left corner of the box, concluding correctly that starting a red ball there made no difference to the probability of it (or any other ball) being the first to exit.

You were right about the top left corner. Amazingly, Maxwell was right too: his molecular velocity distribution is the correct one, although this was not experimentally verified until 60 years later. Sometimes System 2's highest achievements depend on System 1's insights into the way things work.

These claims about the psychology and the history of probability are covered in more detail in my recent book *Tychomancy*. Tyche means "luck" or "chance" in Greek; the title points, then, to an almost magical ability to know facts about the probabilities of things. Sometimes, as Kahneman has shown, we fumble those facts. But we would have nothing to fumble in the first place if our System 1 were not working behind the scenes to supply us with basic probabilistic particulars.

System 1 contains a jumble of heuristics, but it also houses a coterie of experts, quietly generating those instincts about the behaviour of things that we call physical intuition. It is this mental *mélange*, taken as a whole, that makes for the mixture of incompetence and insight, of idiocy and intelligence, that is so recognisably human.