CHAPTER 3

Biases: Mistaking Intuition for Irrationality[*]

> Mental illusions should be considered the rule rather than the exception.
>
> *Richard Thaler*[1]

> Kahneman and Tversky are more responsible than anybody for the powerful trend to mistrust human intuition and defer to algorithms.
>
> *Michael Lewis, The Undoing Project*[2]

When psychology struggled for its independence from philosophy in the late 19th century, intuition was one of its casualties. In a radical turn from philosophers' and theologians' view of intuition as "direct" knowledge and as one of the highest intellectual powers, intuition became seen as a primitive, impulsive, and developmentally earlier mental process. Studies in the 1920s sought to show that children and those with cognitive impairments excel in making rapid, intuitive judgments of physical quantities; results were inconclusive.[3] Others tried to show that women's judgments of children's character are more intuitive than male's rational judgments, again without finding such a difference in comparison to the judgments of character made by children's teachers. Behaviorists such as B. F. Skinner did not even deem the study of intuition (and other nonobservable processes) worthy of rigorous science, distancing themselves from what they saw as unscientific mysticism. Between 1985 and 2004, an analysis of 2.1 million articles in the *PsychINFO* database found only 355 peer-reviewed articles that featured "intuition" in the title.[4] There are,

[*] This chapter is partly based on Gigerenzer (2018).

[1] Thaler (1991).

[2] Lewis (2017). The quote is from the front flap.

[3] For an overview of early-20th-century studies on intuition, see Osbeck & Held (2014).

[4] Haidt & Kesebir (2008). The search included the words *intuition*, *intuitive*, and *intuitionist.* In a search conducted in 1978, Bastick (1982) reported only 91 studies with the word *intuition* in the title or abstract. It has been unusual for psychologists to study intuition for a long time.

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however, notable exceptions to this general dismissal. Jean Piaget explained that his studies of the development of intuitions about time and motion were prompted by questions suggested by Albert Einstein, and his research in turn stimulated contemporary analyses of intuitive physics and intuitive psychology.[5]

By the 21st century, the association of intuition with women was dropped in psychology, albeit continuing in parts of the general public. Yet, after being stripped of gender, intuition has once again been opposed to reason and, like female intuition, has been classified as inferior. The polarity morphed into two supposed systems of reasoning, referred to as Systems 1 and 2. System 1 is said to be fast and unconscious, to work by intuition and heuristics, to lack rationality, and to be the source of error. System 2, in contrast, is said to be slow and conscious, to work by logic and statistics, and to make no apparent errors in reasoning.[6] At the same time, System 2, as mentioned in Chapter 1, is held responsible for the errors System 1 makes by failing to detect and correct these.[7] Just as men were once held responsible for preventing females from committing mistakes, a logical system is now assigned the paternalistic task of keeping the intuitive system in check. Logical reasoning is always rational, we are told, while intuition is not.

[5] See Gruber & Vonèche (1977), p. 548. On the origins of intuitive concepts, see Carey (2009).

[6] Dual-process theories come in many kinds, creating a scattered, moving, and blurred framework. The first dual-process models by psychologists Jonathan Evans and Peter Wason, published in the mid-1970s, made somewhat different claims. They included the idea that deliberative reasoning is typically used to rationalize a conclusion that has been arrived at by intuition, which was later mostly dropped (see Mercier & Sperber, 2018, pp. 43–48, for a history). Sloman (1996) and many others proposed different lists of oppositions, without emphasizing that one is superior to the other, while Evans & Stanovich (2013) had second thoughts and spoke of "Type-1 and Type-2 processing," dropping their earlier terminology of System 1 and System 2, in response to criticism (e.g., Gigerenzer & Regier, 1996). That change avoided the unrealistic implication that there were two different systems in the brain, but maintained two different kinds of processes. However, as we will see, the heuristic processes on which intuition and deliberate thinking is based are typically the same (Kruglanski & Gigerenzer, 2011). In this book, I refer to dual-systems theories which assume (i) an opposition between the two systems and (ii) the superiority of System 2, as popularized by Kahneman (2003, 2011a). It is default-intervenist, meaning that "system 1 quickly proposes intuitive answers to judgment problems as they arise, and system 2 monitors the quality of these proposals, which it may endorse, correct, or override" (Kahneman & Frederick, 2005, p. 267). Let me point out that the opposition between intuition, heuristics, and unconscious on the one hand, and deliberate, rule-based (logic or probability) and conscious on the other hand, which appears to be the key part of most dual-process theories, is not shared generally in psychology. For instance, in Bayesian theories in cognitive science and cognitive neuroscience, unconscious processes are modeled by "optimal" statistical algorithms (Chater & Oaksford, 2008), and in theories of ecological rationality, heuristic processes are part of conscious decision-making (Gigerenzer et al. 2022a).

[7] Kahneman (2002), p. 471.

Logic Versus Intuition

Imagine a patient with a serious heart condition who is pondering whether or not to have a potentially risky surgery. They consult with their doctor regarding their prospects. The doctor informs them:

Five years after surgery, 90 percent of patients are alive.

The patient's intuition may tell them that the doctor is encouraging them to decide in favor of surgery, which they might do. But what if the doctor had said:

Five years after surgery, 10 percent of patients are dead.

In this case, the patient might infer that the doctor is presenting a warning and might think twice before forgoing the surgery. Studies show that more people are willing to agree to a medical treatment if the doctor uses a *positive frame* (90 percent alive) than a *negative frame* (10 percent dead).[8] This phenomenon is known as the framing effect – people listen to how a message is framed and may change their decision.

Should a patient listen to how the doctor frames a message? Economic theory has traditionally not considered psychological factors such as making implicit recommendations by framing a message. However, an influential group of behavioral economists, led by psychologists Daniel Kahneman and Amos Tversky, took logic and Homo economicus more literally than many economists and went a step further. Any difference between human judgment and abstract logic was perceived as a fault in human intuition.[9] Accordingly, patients should not listen to how a doctor frames the message because the positive and negative frames are logically equivalent. Patients who decide for or against surgery on the basis of the frame are said to lack rationality and suffer from a cognitive bias.

Commenting on the surgery problem, behavioral economist Richard Thaler and legal scholar Cass Sunstein concluded that "framing works because people tend to be somewhat mindless, passive decision makers" and framing thus offers a "brief glimpse at human fallibility."[10] Kahneman has considered the attention paid to framing as "embarrassing" evidence for cognitive biases, which people repeatedly fall for: "in their stubborn appeal, framing effects resemble perceptual illusions more than

[8] Moxey et al. (2003). [9] Kahneman (2002, 2011a).
[10] Thaler & Sunstein (2008), pp. 39–40.

computational errors."[11] (Although it should be acknowledged here that Kahneman appears to have qualified his contentions over the years, later speaking of both the marvels and flaws of intuition.[12]) In this view, logical thinking is the sole ingredient of rationality, while intuition is a steady source of bias.

Intuition Versus Rationality Anew

The framing effect is just one of a long list of transgressions that intuition allegedly commits against reason according to influential psychologists and behavioral economists, whose research focused on the flaws of intuition. These "biases" have attained the status of truisms and provided justification for new paternalistic policies, popularly known as *nudging*, adopted by governments in the UK, the USA, and elsewhere. The argument is not simply that people sometimes make mistakes or lack training in logical or statistical thinking – that would be nothing new. Rather, something inside our mind is said to make virtually everyone err in the same systematic way, with little hope of remedying the problem. In Dan Ariely's words, "we are not only irrational, but *predictably irrational* – that our irrationality happens the same way, again and again."[13] The argument leading from biased intuition to governmental paternalism – in short, the irrationality argument – consists of three assertions and one conclusion:

Biased intuition: People's intuitions are systematically biased and lack rationality.
Stubbornness: Intuition is stubborn and, like visual illusions, hardly educable.
Real-world costs: Biased intuition incurs substantial costs such as lower wealth, health, and happiness.
Conclusion: Biased intuitions justify governmental paternalism.

These three assumptions – biased intuition, stubbornness, and costs – imply that chances are slim to nonexistent of the public ever learning or being educated out of their biases; instead, governments need to step in and nudge them into proper behavior.[14] This new paternalism aims not at protecting people from external dangers or imperfections of the market, but from the enemy within: their own irrationality. Rationality, from this perspective, entails *always* obeying the logical axioms of consistency, maximizing one's expected utility, and updating probabilities via Bayes' rule. Let us call this ensemble *logical rationality*, for short. Maintaining that

[11] Kahneman (2011a), pp. 373–374; Kahneman & Tversky (1984), p. 343.
[12] Kahneman (2011b). [13] Ariely (2008), p. xviii. [14] Thaler & Sunstein (2003).

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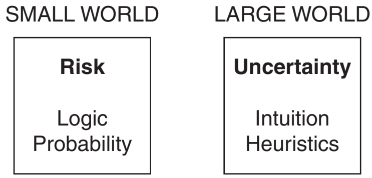

Figure 3.1. Risk versus uncertainty. In situations of risk, all possible future events, along with their consequences and probabilities, are known. In situations of uncertainty, that knowledge is not attainable. Uncertainty requires more than logic and probability: intuition and heuristics.

patients should pay attention solely to the logical part of a doctor's message, not to its psychological part, is an instance of logical rationality. Note that logical rationality is content-free and thus knowledge, intelligence, emotion, and common sense are assumed to be of no relevance for rational decision-making.

What if logical rationality is of value only for some problems and not for all? If logic were all we needed, our psychology would not have evolved into what it is, with its intuitions, heuristics, emotions, and social intelligence. Instead, our brains would have become superb calculating machines.

The crucial point is that logical rationality assumes a *small world* of known risk, as in games of roulette or slot machines with known payoffs, where the expected loss can be calculated and intuition is of no additional help. In a situation of risk, everything that can happen in the future is known, including all consequences of actions and their probabilities (Figure 3.1). Our brain, however, evolved to deal with a world of uncertainty. Uncertainty inhabits our lives in many forms: uncertainty about diagnosis and treatment, the intentions of others, financial markets, warfare, pandemics, natural disasters, and the future in general. I return to this important distinction in Chapter 5.

My point is not that intuition never errs. Of course it can err, just as logical analysis does; that's why we need both. Instead, my argument is that, in situations of uncertainty, relying on logical rationality can be seriously misleading – as can mistaking intelligent processes to deal with uncertainty for biased intuition.

The Bias Bias

It is striking how much emphasis is placed on pointing out errors in intuition and how little reflection occurs on whether logical rationality is, in fact, a reasonable norm. That is not to say that the value of intuitive judgments is consistently denied in the literature on cognitive biases. However, every single experiment in this literature was designed to show, and concluded, that intuition fails. There appears to be a group dynamic that leads researchers to hunt for the next new bias. I call this extreme desire to attack intuition the *bias bias*:

Bias bias: The tendency to see systematic biases in intuition even if there is only unsystematic error or no verifiable error at all.

Let us look at several celebrated biases that are widely taken for genuine cognitive errors.

Framing

As I have mentioned, in a world of risk, where knowledge is certain, the framing of options (such as positive vs. negative) should have no impact on choice. Neoclassical economics assumes that rationally acting people have stable preferences and changing these according to the framing of a message is seen as a preference reversal. However, certainty does not exist for most important decisions, such as whether to undergo a dangerous surgery. Under uncertainty, preferences should not all be fixed, and asking for advice and information can be helpful. By framing an option, a speaker can communicate information that is not contained in the verbatim message, but which the intelligent listener is able to decode and incorporate into the choice accordingly. This decoding is known in the study of language comprehension as *invited inferences*, which are largely intuitive and more intellectually challenging than logical inferences. The great physiologist Hermann von Helmholtz spoke of *unconscious inferences*, which are the very backbone of human intelligence.

Surgery

Consider the surgery problem again. For the patient, at issue is not logical consistency, but a life-and-death decision. To that end, the two relevant questions are: Is expected survival higher with or without surgery? Do possible harms associated with surgery lead to reduced quality of life? Neither "90 percent alive" nor "10 percent dead" provides any of this information. What the patient needs to know is the survival rate *without* surgery along with the potential benefits and harms of surgery. This essential information is missing from the doctor's message. Thus, participants have to rely on their social intelligence to make an informed guess.

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By framing the option, speakers can convey information about the missing information, something listeners tend to understand intuitively. Experiments showed that if the no-surgery option was worse than surgery ("fewer patients survive without surgery"), then 80–94 percent of the speakers (doctors) chose the "survival" frame. When, by contrast, no surgery was the better option ("more patients survive without surgery"), then the survival frame was chosen less frequently.[15] Thus, by choosing a survival frame, the doctor can communicate that surgery has a substantial benefit compared to no surgery and can make an implicit recommendation.

There are various reasons why doctors may omit information or not explicitly communicate recommendations. In the USA, for instance, tort law encourages malpractice suits, which fuels a culture of blame in which doctors fear making explicit recommendations.[16] By selecting a positive or negative frame, physicians can indirectly communicate their belief as to whether surgery has a substantial benefit compared to no surgery. And most patients understand the message.

In an uncertain world such as that of medical treatment, logically equivalent frames are not necessarily informationally equivalent. Here, following logic can cost lives.

Is the Glass Half Full or Half Empty?

The choice of frame can also implicitly communicate other relevant information. The mother of all framing problems makes that clear:

The glass is half full.
The glass is half empty.

Once again, both frames are the same logically, but not psychologically. Imagine that there are two glasses on a table, one full and one empty (Figure 3.2). You are asked to pour half of the water in glass (b) into glass (a). Then you are requested to take the half-empty glass and move it to the edge of the table. Which would you pick? Most likely, you would intuitively pick the glass that was previously full.

An experiment showed that most people did exactly that. Likewise, when asked to take the half-full cup, they chose the one that was previously empty.[17] Framing conveys unspoken information, and a careful listener understands that half full and half empty are not identical.

[15] McKenzie & Nelson (2003). [16] Gigerenzer (2014a); Hoffman & Kanzaria (2014).
[17] Sher & McKenzie (2006).

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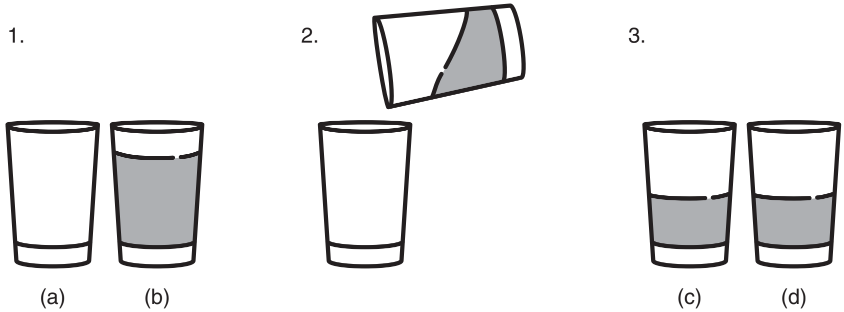

Figure 3.2. Which glass is half full, which half empty? 1: Two glasses, (a) empty and (b) full. 2: Half of glass (b) is poured into glass (a). 3: Two glasses, (c) half full, (d) half empty.

The intuitive ability to use a frame to communicate unspoken information, as well as to decode this information, is based on heuristics.[18] For instance, listeners expect that what and how the speaker communicates is relevant – the *relevance maxim*. An example is the implication that a speaker is likely making an unspoken recommendation when using a positive frame for an option, whereas a negative frame likely indicates a warning. In general, the ability to listen carefully and pay attention to how messengers frame messages is a form of intelligence, not a bias of intuition.[19]

The Asian Disease Problem Reassessed

Perhaps the most widely cited example of a framing effect stems from the "Asian disease problem," which figures prominently in virtually all textbooks:[20]

Imagine that the USA is preparing for an outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:

[Positive Frame:]
If Program A is adopted, 200 people will be saved.
If Program B is adopted, there is a 1/3 probability that 600 people will be saved and a 2/3 probability that no people will be saved.

[18] See, for example, Grice (1989); Hertwig & Gigerenzer (1999); Sperber & Wilson (1986).
[19] See, for example, Sher & McKenzie (2006).
[20] Kahneman (2003); Tversky & Kahneman (1981).

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[Negative Frame:]
If Program A is adopted, 400 people will die.
If Program B is adopted, there is a 1/3 probability that nobody will die and a 2/3 probability that 600 people will die.

Kahneman and Tversky argued that the positive and negative frames are logically equivalent, meaning that framing should not alter the preference order. Nevertheless, when given the positive frame, most people favored Program A, but, when given the negative frame, favored Program B. This difference was interpreted as evidence that people are risk-averse for gains (choosing the "certain" option in the positive frame) and risk-seeking for losses (choosing the "risky" option in the negative frame).[21] In this purely logical interpretation, the responses to the Asian disease problem – just as to the surgery problem – violate the assumption of stable preferences and show that people's intuitions can be easily manipulated.

Now recall the psychological analysis of the surgery problem: If people notice that part of the information is omitted, such as the effect of no surgery, they tend to make intuitive inferences. The psychologist Anton Kühberger and I noted that the Asian disease problem is of a similar nature: The risky option is always spelled out entirely in both frames (e.g., a 1/3 probability that 600 people will be saved and a 2/3 probability that no one is saved), whereas the "certain" option is never complete. For instance, it communicates that 200 people will be saved, but not that 400 will not be saved. This systematic asymmetry matters neither from the logical norm of *description invariance* nor for prospect theory, given that the framing in terms of loss and gains is preserved. But it should matter if people question the intentions underlying this asymmetry and make intuitive inferences. To test these two competing explanations – logical error or intelligent inference – all that needs to be done is to complete the missing options in both frames. Here is the complete version for the positive frame:

If Program A is adopted, 200 people will be saved and 400 people will not be saved.
If Program B is adopted, there is a 1/3 probability that 600 people will be saved and a 2/3 probability that no people will be saved.

If any of the logical explanations given – people's susceptibility to framing errors, their risk-aversion for gains and risk-seeking for losses, or the value function of prospect theory – were true, this addition should not

[21] Tversky & Kahneman (1981).

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matter. However, Kühberger found that it changes the entire result. When people were provided with the full information, the effect of positive versus negative frames disappeared. Subsequent studies replicated this striking finding.[22] As further studies indicated, many people notice that the information is asymmetric and infer that the incomplete option means that *at least* 200 people are saved because, unlike in Program B, the information for how many will not be saved is not provided.[23] In other words, they infer that Program A guarantees that 200 or more people will be saved, as opposed to exactly 200.

Thus, people's judgments appear to have little to do with loss-aversion or unstable preferences due to positive versus negative framing. The asymmetry of the information communicated instead drives the entire effect. When supplied with incomplete information, people have to make intelligent inferences.

Intelligent Inferences Mistaken for Biases

In all of these cases, the same bias bias is seen: mistaking intelligent intuitive inferences for biases. Frames carry information beyond their literal content, meaning that their interpretation requires not logical, but psychological, analysis. The bias bias emerges from a view that eliminates all psychology by assuming that logically equivalent statements must be informationally equivalent. This principle of "descriptive invariance" has been hailed as an essential condition for rational choice.[24] However, the art of reading between the lines is more cognitively demanding than the narrow logic of descriptive invariance.

Once again, there is a difference between the natural and social sciences. Framing has long been considered an art in mathematics and physics, as the importance of notation and number representation illustrates. For example, Newton and Leibniz had different notations for the calculus, each having its advantages, which are discussed to the present day. Although logically equivalent, they are not identical. The physicist Richard Feynman pointed out the importance of simultaneously working with different formulations of the same physical law, even if they are logically equivalent: "Psychologically they are different because they are completely unequivalent when you are trying to guess new laws."[25]

[22] See, for example, Kühberger (1995); Kühberger & Tanner (2010); Mandel (2001); Tombu & Mandel (2015).
[23] Mandel (2014).
[24] Tversky & Kahneman (1986), p. S253.
[25] Feynman (1967), p. 53.

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In sum, the principle of logical equivalence or description invariance is a poor guide to understanding how human intelligence deals with an uncertain world where not everything is, or can be, stated explicitly. It misses the very nature of social intelligence, the ability to make inferences beyond the bare information given.[26] Logic is without doubt a tool of rationality, but not the exclusive one in the cognitive toolbox.

Intuitions About Randomness

Psychology classrooms often resemble magic shows, where professors perform tricks to demonstrate how everyone's intuition can be fooled. Consider a stock-in-trade attraction, where someone throws a coin to see whether it lands heads (H) or tails (T). The quiz is:

You take a fair coin and flip it four times in a row. Which string will you more likely observe?

HHH
HHT

Most people's intuition says that HHT is more likely. Yet, a psychology professor may argue that the intuition is faulty because the two strings have the same probability of occurring. The probability of a head is always the same as of a tail; thus, the probability of each string is the same, the students are told. Upon reflection, they may be inclined to concede that the intuition was wrong, even though it still intuitively feels right. This has happened to many participants in psychological experiments, and it appears to prove the first two assertions about biased intuition: that people lack rationality and that intuition is hardly educable: Even after being proven wrong, people stubbornly hang on to their biased intuition. The bias has a name, the *law of small numbers*, which is one of the two key experimental findings on intuitions of randomness:

1. **The law of small numbers:** People think a string is more likely the closer the number of heads and tails corresponds to the underlying equal probabilities. For instance, the string HHT is deemed more likely than HHH, and HHHHHT is deemed more likely than HHHHHH.
2. **Irregularity:** If the number of heads and tails is the same in two strings, people think that the one with a more irregular pattern is more

[26] Bruner (1973).

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H	H	H	H	H	H	H	H	T	T	T	T	T	T	T	T
H	H	H	H	T	T	T	T	H	H	H	H	T	T	T	T
H	H	T	T	H	H	T	T	H	H	T	T	H	H	T	T
H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T
✓	✓+	+	+					✓	+						

Figure 3.3. Throwing a fair coin four times. Is a string of HHH or HHT more likely? There are 16 possible sequences of four tosses of a fair coin, each equally likely. In three of these, there is at least one string HHH (check mark), while HHT occurs in four of these (plus sign). Consistent with the intuition of many people, encountering the sequence HHT is more likely.[27]

likely. For instance, the string HHTHTH is deemed more likely than HTHTHT.

Most people feel that there is something unusual in the string HTHTHT, where heads and tails strictly alternate, and that the irregular string HHTHTH is more likely to be obtained. Yet, that too is considered a fallacy for the same reason: The probability of both strings is the same. Both phenomena have been called systematic biases. But why should people have faulty intuitions about randomness in the first place? Some researchers have suggested that random devices did not exist during most of human evolution, and thus our minds have not developed proper intuition. This explanation, however, accepts the claim that people's intuitions are wrong in the first place. Let us have a closer look.

The Law of Small Numbers

Is it indeed equally likely that one will encounter a string of HHH or of HHT when flipping a coin four times in a row? Surprisingly, the answer is that HHT is more likely.

Figure 3.3 shows why. There are 16 possible sequences that can result from throwing a coin four times. These sequences are all equally probable. In four of these, one encounters an HHT, as marked by a "+". But an HHH is found in only three sequences, as shown by a check mark. Thus, the relative frequency of encountering at least one HHT is 4/16 = .25 and that of HHH is 3/16 = .19. People's intuition that an HHT is more likely to be encountered than an HHH in a sequence of four flips turns out to be correct.

Another way to understand this result is that two strings of HHH overlap in the first column of Figure 3.3, whereas no such overlaps occur

[27] Hahn & Warren (2009).

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H	H	H	H	T	T	T	T
H	H	T	T	H	T	H	T
H	T	H	T	H	H	T	T
✓	+						

Figure 3.4. The special case where the length of the string (here three) is the same as the length of the sequence ($k = n$). Here, the chance of encountering an HHT and an HHH are the same. But that does not hold in all other cases, as Figure 3.3 illustrates.

(or are even possible) for HHT. Similarly, it can be shown that HHT is likely to be encountered *earlier* than HHH: The expected waiting time for HHT is eight tosses of a coin, compared with 14 tosses for HHH.[28]

Our example was with four throws. Consider now the general case. Let k be the length of the string of heads and tails judged (which is three in the example above), and n be the total sequence (number of tosses, which is four in the example). Thus, $k \leq n$. Now we can specify the general principle under which people's intuition is ecologically rational:

If $k < n <$ infinite, a string of Hs with a single alternation such as HHT is more likely to be encountered than a pure string such as HHH.

The term *ecologically rational* means that statements about the rationality of judgments need to be qualified with respect to ecological conditions: here, the length of the string and that of the sequence. In sum, the intuition that HHT is more likely to be encountered than HHH is not generally an error. It is only so in two specific conditions: if a person has seen exactly as many throws as the string to be judged and if a person has seen an infinitely long string, which is impossible for a mortal being.

Figure 3.4 shows the special condition where the number of tosses and the string is of equal length. Here, the chance of encountering an HHH and an HHT is the same. There are eight possible outcomes, with one of each string.

In Figure 3.3, the string is a proper sample of the number of tosses. In statistical terms, sample statistics need not be the same as population statistics, which is precisely the situation here. In Figure 3.4, the sample is the population. If you are still not convinced, consider this bet:[29]

The law-of-small-numbers bet: You flip a fair coin 20 times. If this sequence contains at least one HHHH, I pay you \$100. If it contains at least one HHHT, you pay me \$100. If it contains neither, nobody wins.

[28] Ibid. [29] Hahn & Warren (2010).

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If HHHH and HHHT were equally likely to be encountered, then the two players should break even. But, in fact, the person who accepts the bet can expect to lose in the long run. For 20 flips, the probability that you will see at least one HHHH is about 50 percent, but the chance of an HHHT is around 75 percent.[30] For the same reason, a gambler who watches the outcomes of the roulette wheel in a casino for half an hour can more likely expect to see a string of three reds followed by a black than a string of four reds. In this situation, believing in the law of small numbers pays.

The phenomenon that people expect more alternations than those predicted by probability theory has been sometimes linked to the gambler's fallacy. Yet, that connection is mistaken, as can be deduced from the ecological rationality condition. The gambler's fallacy refers to the intuition that, after witnessing a string of, say, three heads, one expects that the next outcome will be more likely tails than heads. This would be a true fallacy because it corresponds to the condition $k = n$. In other words, a total of four throws is considered, either HHHH or HHHT, and there is no sample k with the property $k < n$.

Irregularity

The second alleged misconception regarding chance is that people believe that irregular sequences are more likely. Consider the following two sequences:

HTHTHT
HTTHTH

Here, the number of heads and tails are now identical, but alternations are regular in the first string and irregular in the second. Psychological research documented that most people find the more irregular string more likely.

Once again, this intuition is not a fallacy for the same reason as before: If $k < n < \infty$, then the irregular sequence HTTHTH is more likely than the regular one. The expected waiting time to get a HTTHTH is 64 flips, compared with 84 for HTHTHT (and 126 for HHHHHH).[31] This can be verified in the same way as with Figure 3.3.

In sum, people's intuition that irregular alternations are more likely to be encountered reflects an astonishingly fine-tuned sensitivity to the statistics of finite samples. The intuition is erroneous in only one special

[30] Hahn & Warren (2009). [31] See Hahn & Warren (2009).

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case, when the number of throws is exactly the same as the string (Figure 3.4).

Fine-Tuned Intuition Mistaken for Bias

In the literature on flawed human intuition of randomness, no distinction appears to have been made between the one specific case where it is indeed flawed and all the other instances where intuition is actually right.[32] Rather, intuitions have been generally declared erroneous. Whatever the explanation, the alleged bias was seen to demonstrate the "stubbornness" of intuition: "For anyone who would wish to view man as a reasonable intuitive statistician, such results are discouraging."[33]

In summary, people's intuitions about chance have been interpreted as systematically flawed because they (i) fall prey to the law of small numbers and (ii) confuse irregularity with chance in both the recognition and production of randomness. An ecological analysis, by contrast, shows that if $k < n < \infty$, which is the typical window of experience, people's intuitions are, in fact, correct. The general insight is that the properties of the underlying chance process (such as equal probability) do not match the properties of small samples, a phenomenon known as *biased sample estimators* in statistics. In other words, people's intuitions were evaluated against the wrong normative standard, one that does not capture the properties of samples.

In the next section, "The Hot Hand Fallacy," we will see that the same oversight applies to an allegedly illusory intuition shared by many coaches and players.

The Hot Hand Fallacy: Professional Intuition Mistaken for Bias

Most sport fans can recall magical moments when a player is "on fire," "in the zone," "in rhythm," or "unconscious." This temporarily elevated performance is known as the *hot hand*. For players and coaches, the hot hand is a common experience. It resembles what my late colleague Mike Csikszentmihalyi called "flow," a time in which performance increases without deliberation; jazz musicians, professional writers, and many others also report such moments.[34] According to some researchers, however, this belief is an illusion, which has been dubbed the *hot hand fallacy*.[35] In Thaler and Sunstein's words, "It turns out that the cognitive illusion is so powerful that most people (influenced by their Automatic System) are

[32] Kahneman & Tversky (1972). [33] Ibid., p. 445. [34] Csikszentmihalyi (2008).
[35] Gilovich et al. (1985).

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unwilling even to consider the possibility that their strongly held beliefs might be wrong."[36] "It turns out that the 'hot hand' is a myth," they assert; "to date, no one has found it."[37] Nevertheless, coaches and players stubbornly cling to their experience of the hot hand, apparently further evidence that cognitive illusions resemble visual illusions. Even the website of the National Collegiate Athletic Association (NCAA) sided against the coaches and warned of believing in magic: "Streaks and 'hot hands' are simply illusions in sports. And, it is better to be a scientist than be governed by irrational superstition." The hot hand fallacy served as an explanation for various vices in financial markets, sports betting, and casino gambling. Once again, the suspected fallacy was presented as evidence for the irrationality of intuition.

From an economic view, however, the claim that this intuition is stubbornly wrong is most puzzling. Professional coaches and players presumably have no incentives to be wrong, only to be right. Why then would such an erroneous belief persist? Economist and Nobel laureate Gary Becker once remarked to me that coaches see when a player in the other team is hot and then send an extra player to cut their streak short.[38] For that reason, he concluded, one cannot find the effects of getting hot in the performance streaks that psychologists were analyzing. His was a reasonable objection, but the psychologists assessing the existence of the hot hand had already taken this into consideration and analyzed data from free shots, where no players are allowed to interfere. Even here, they could not find any trace of a hot hand in the data.

The Hot Hand Exists

It took some 30 years and two smart economists, Joshua Miller and Adam Sanjuro, to show, using the original free shot data, that the hot hand is not a myth.[39] For simplification, I apply the same line of analysis used earlier to explain the intuitions about randomness; Miller and Sanjuro took a different approach.

In the original study, 26 shooters from Cornell University each made 100 free shots from a fixed distance with varying locations. The authors of that study posited that there is no hot hand if the frequency of a hit after three hits equals that of a miss after three hits. When looking at all occurrences of three hits and recording how often these were followed

[36] Thaler & Sunstein (2008), p. 31. [37] Ibid., p. 33.
[38] G. S. Becker (1994, personal communication); see also Raab et al. (2012).
[39] Miller & Sanjuro (2018).

by another hit, they found that the number was the same for all but one player – an anomaly that can be attributed to chance. Thus, the conclusion was that the hot hand does not exist and that belief in it is a fallacy.

Let us take a closer look at this argument. As shown in Figure 3.3, tails after two heads is more likely than another head if the length of the string is smaller than that of the entire sequence. Now replace heads with hit, tails with miss, and the fair coin with a player who shoots from a distance where there is a probability of .50 of scoring a hit. If a player makes n = 4 free shots, there are 16 sequences with equal probabilities. In six of these sequences, one can test the hot hand because these have HH followed by either H (hit) or T (miss). If there were no hot hand, we would observe a miss after two hits in four of these six sequences and a hit after two hits in only three (the four plus signs and the three check marks in Figure 3.3). That is, in two out of the 16 possible sequences one would observe a hit, in one sequence a hit and a miss, and in three a miss. The expected relative frequency of a hit after two hits (HHH) is therefore 2 + 0.5 out of 6, which is .42. Because HHH should be less often observed than HHT, finding a relative frequency of .50 of HHH in the free shots instead of the expected .42 actually indicates a hot hand.

The same holds for a sequence of 100 free shots and strings of length 4. Once again, we are dealing with k = 4 (the length of the string) and n = 100; that is, the ecological condition $k < n < \infty$ is in place. In a reanalysis of the original data, a substantial number of the shooters showed a pattern of performance consistent with the hot hand.[40] Across players, the hot hand boosted performance by 11 percentage points, which is substantial and roughly equal to the difference in the field goal percentage between the average and the very best three-point shooter in the National Basketball Association (NBA).

Coaches and players thus have good reason to maintain their belief in the hot hand and do not need to be nudged out of their "stubborn" intuition.

Generality of the Bias Bias

These examples of the bias bias may suffice to gain a general idea about the war against intuition. The list could be continued with the Linda problem,[41] base rate neglect,[42] loss-aversion,[43] priming,[44] and other apparent

[40] Ibid. [41] Hertwig & Gigerenzer (1999). [42] Gigerenzer et al. (2021).
[43] Gal & Rucker (2018). [44] Pashler et al. (2012).

biases that are no errors in the first place, or errors only under special conditions, or cannot be replicated.[45] In general, there are five general principles underlying the bias bias:

1. **Logically equivalent frames are mistaken as informationally equivalent**: Framing and the logical norm of description invariance are key examples.
2. **Biased sample estimators are mistaken for people's biases:** The statistics of small samples can systematically differ from the population parameters. Intuitions about chance and the hot hand are examples.
3. **Experimenters' sampling of questions is biased:** Overconfidence – defined as mean confidence minus percent correct – results from selected questions that are untypical, but it disappears when questions are chosen representatively.[46]
4. **Unsystematic errors are mistaken for systematic biases:** Confusing regression to the mean with a systematic error is an example. Unsystematic errors have been misinterpreted as a miscalibration (another version of overconfidence)[47] as well as an overestimation of small risks and an overestimation of large risks.[48]
5. **Situations of risk (where probability theory can provide the best answer) are not distinguished from situations of uncertainty (where heuristics can be superior):** This is the key problem underlying most erroneous diagnoses of biases.

The history of statistics has taught us that normative claims require a careful analysis of the assumptions made. In studies that try to show errors of intuition, surprisingly little thought is given to what constitutes rational judgment, an apparent contradiction referred to as the *irrationality paradox*.[49] Once again, that is not to say that intuition never errs. At issue is a full-fledged bias bias against intuition.

Citation Bias

Alongside the bias bias, the citation bias is a second weapon in the war against intuition. A citation bias occurs when positive findings are systematically less often cited than negative findings. Imagine 110 articles on

[45] See Gigerenzer (1996, 2018); Gigerenzer et al. (2012).
[46] Gigerenzer et al. (1991); Juslin et al. (2000).
[47] Dawes & Mulford (1996); Erev et al. (1994); Pfeifer (1994).
[48] Hertwig et al. (2005).
[49] Gigerenzer (2004a).

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intuition that report largely successful performance and four articles that report errors. If the four are cited more often than the 110, that is a clear case of citation bias. Citation bias is widespread in media that amplify negative stories, scandals, and misfortunes to attract attention or satisfy a hidden agenda. Science is also not free of selective reporting, with some fields more susceptible than others.

As mentioned, the focus of the new war against intuition is on judgments about chance, frequency, and randomness – in short, statistical intuitions. Swiss psychologists Jean Piaget and Bärbel Inhelder, who were among the first to systematically study the development of intuitions of chance in children, concluded that children's intuitions approximate the laws of statistics by age 12.[50] Similarly, experiments with adults up to the 1970s concluded that people's intuitions are in good, albeit not perfect, agreement with the laws of statistics. In 1967, for instance, psychologists Cameron Peterson and Lee Roy Beach arrived at this conclusion after reviewing 110 articles in their paper aptly (apart from the gender bias) entitled "Man as an Intuitive Statistician." They concluded that intuitions "are influenced by appropriate variables and in appropriate directions" while also pointing out cases where intuitions deviate. Overall, the 160 experiments in these 110 articles show that the laws of statistics provide "a good first approximation for a psychological theory of inference."[51]

Seven years later, Tversky and Kahneman challenged this conclusion in a review paper entitled "Judgment under Uncertainty: Heuristics and Biases," summarizing four articles they had published on putative cognitive biases.[52] They concluded: "In making predictions and judgments under uncertainty, people do not appear to follow the calculus of chance or the statistical theory of prediction."[53] The question arises why people's intuitions about chance took a nose-dive in the 1970s and no longer approximated statistical theory thereafter. One might assume that the research community had discussed this question and sought an answer. Instead, a citation bias made the contradicting conclusions disappear.

Figure 3.5a reveals the extent of the citation bias. By 2020, "Man as an Intuitive Statistician" was cited 479 times, while "Judgment under Uncertainty: Heuristics and Biases" was cited over 15,000 times.[54] As a

[50] Piaget & Inhelder (1951/1975). [51] Peterson & Beach (1967), pp. 42–43.
[52] Tversky & Kahneman (1974). [53] Kahneman & Tversky (1973), p. 237.
[54] Lejarraga & Hertwig (2021). Citations on Google Scholar are higher, but reveal the same citation bias, 37,331 versus 1,165 citations by August 2020, for Tversky & Kahneman and Peterson & Beach, respectively.

consequence, the collective memory of a large body of experimental research has been largely wiped out.

This example is not the exception to the rule. Consider another pair of articles, also seven years apart. In 1965, Ward Edwards and colleagues published a review of whether intuitive opinion change follows Bayes' theorem: "It turns out that opinion change is very orderly, and usually proportional to numbers calculated from Bayes' theorem – but it is insufficient in amount."[55] The review found that people are conservative Bayesians, that is, Bayesians who give too much weight to base rates. In contrast, in an article published in 1972, Kahneman and Tversky concluded: "In his evaluation of evidence, man is apparently not a conservative Bayesian: he is not Bayesian at all."[56] Once more, the question of why people's intuitions looked approximately Bayesian in experiments only until 1970 was rarely if ever posed in the research that found intuition wanting. And yet again, a citation bias took care of the problem (Figure 3.5b). The message that people are not Bayesians at all became common wisdom.

The citation bias is not limited to these classical experiments.[57] For instance, the experiments on framing by Craig McKenzie and his research group in San Diego or the experiments on the various phenomena labeled overconfidence by Peter Juslin and his collaborators in Sweden are rarely, if ever, mentioned in texts that present framing or overconfidence as systematic biases.[58] Similarly neglected is the research on the Bayesian mind in cognitive science and cognitive neuroscience that concludes that memory, categorization, and reasoning are Bayesian.[59] The citation bias, the bias bias, and the lack of learning opportunities have turned the narrative of flawed intuitions into an apparent hard fact.

As mentioned at the beginning of this chapter, in addition to biased intuition, two further claims have been made: stubbornness, that is, that intuition is hardly educable; and real-world costs of the alleged biases.

Stubbornness: The Myth That Intuition Is Hardly Educable

An article published in *Nature* entitled *Risk School* posed the question of whether the general public can learn to evaluate risks accurately or whether

[55] Edwards et al. (1965), p. 18.

[56] Kahneman & Tversky (1972), p. 450. Tversky, by the way, was a postdoctoral student of Edwards.

[57] Christensen-Szalanski & Beach (1984).

[58] For example, Juslin et al. (2000, 2007).

[59] For example, Chater & Oaksford (2008); Chater et al. (2006).

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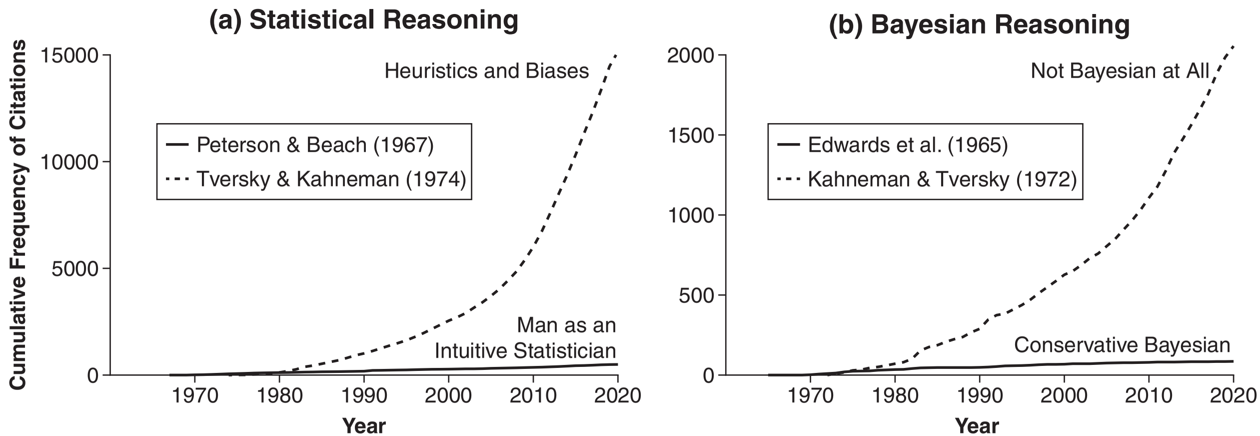

Figure 3.5. Citation bias in favor of articles reporting that people have biased statistical intuitions. (a) Cumulative frequency of citations of Peterson & Beach (1967) and Tversky & Kahneman (1974) from 1967 to August 15, 2020, according to Scopus. (b) Cumulative frequency of citations of Edwards et al. (1965) and Kahneman & Tversky (1972) from 1965 to August 15, 2020. From Lejarraga & Hertwig (2021).

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authorities needed to steer it toward correct decisions.[60] Its author spoke with both the proponents of biases and nudging and with my research group. According to legal scholar Dan Kahan, many specialists conclude that the public will never really be capable of prudent decision-making without any external help, meaning that "risk decision-making should be concentrated to an even greater extent in politically insulated expert agencies."[61] The task of these agencies would be to nudge people into making better decisions.

At the same time, the *Nature* article includes pictures of young children playing with Lego-like toys that my collaborators and I developed. These toys foster good statistical intuitions. And in response to the claim that people are not Bayesian thinkers at all, we showed in a series of studies that most fourth-graders can already find the exact Bayesian answer in tasks tailored to children's interests and by using icons instead of probabilities.[62] The same methods, known as *natural frequencies*, allow the teaching of Bayesian reasoning in less than 2 hours and have been found to generate immediate learning effects that transfer to new problems that are stable over time.[63] Since then, school curricula and medical societies around the world have adopted them, and a Cochrane Review concluded that they are most effective in helping to generate good clinical intuitions.[64] These intuitive representations have also been found to foster doctors' and lawyers' Bayesian intuitions.[65] The difficulties people have with Bayesian thinking are not a result of stubbornly biased intuition, but rather of the fact that, in most parts of the world, neither children nor doctors are taught intuitive ways to understand statistical evidence.

Good representations of numerosities are key to generating good statistical intuitions. Judgments easily go wrong when difficult concepts or representations are used in tests of intuition that most of us have never learned in school. In these cases, a large body of research has, by now, shown that children and adults can learn Bayesian thinking, provided they are given proper representations of numbers.[66] When provided with better education and better intuitive representations of numerosities, people do not require nudging.

These results help to understand why people showed fairly good intuitions about chance before the 1970s and shoddy ones thereafter. In the

[60] Bond (2009). [61] Ibid., pp. 1189–1191. [62] Gigerenzer et al. (2021).
[63] Sedlmeier & Gigerenzer (2001).
[64] Rosenbaum et al. (2010); see also McDowell & Jacobs (2017).
[65] For summaries, see Gigerenzer (2002, 2014a); Gigerenzer et al. (2007).
[66] Gigerenzer & Hoffrage (1995); Gigerenzer (2014a); McDowell & Jacobs (2017).

early 1990s, I wrote to Ward Edwards and asked him why people stopped being conservative Bayesians in the 1970s. A few years earlier, he and Detlev von Winterfeldt had published a book containing a chapter on cognitive illusions. In this book, they reported both their findings that people are approximate Bayesians and Kahneman and Tversky's findings that people are not Bayesians at all, without offering an explanation for this paradox. Edwards' response was emotional and almost 10 pages long. He pointed out that his experiments had been much more carefully designed, conducted, and described in his articles than those of Kahneman and Tversky. Edwards put his finger on the right point, but it took a number of years until the question was truly answered.[67]

What happened is that people's intuitions did not change, but the design of the experiments did. In the experiments by Edwards and others, participants could learn from experience, such as repeatedly drawing red and black balls from urns to guess the composition of the urns' contents. This is known as frequency learning, and it takes time, just as it does in the real world. In the experiments by Kahneman and Tversky, participants were not given the opportunity to learn from experience, but instead were provided with a description of base rates, hit rates, and false alarm rates. This considerably reduced the effort to run an experiment; text problems could be answered in a minute. But it required participants to understand the concept of conditional probabilities, an alien concept that few had learned in school. No such knowledge is required when learning from experience. In other words, the same person can appear to have good or bad Bayesian intuitions, depending on whether they can learn from experience or are provided short descriptions about concepts they may not be familiar with.

Real-World Costs: The Myth of Substantial Costs

The assumption that people lack rationality and stubbornly resist learning does not suffice to justify governmental paternalism such as nudging. After all, it does not follow that violations of logical rationality harm anyone. It is the third assumption that carries weight: that not following logical rationality incurs substantial real-world costs, such as lower wealth, health, and happiness. What is the evidence for this assertion? Psychologists Hal Arkes, Ralph Hertwig, and I analyzed over 1,000 published papers on alleged errors of intuition, defined as deviations from logical norms.[68]

[67] Lejarraga & Hertwig (2021). [68] Arkes et al. (2016).

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The most well-known claim is that if a person violates transitivity, then that unfortunate individual can become a money pump. That is, if a person prefers option A to B, option B to C, and option C to A, and is willing to pay money to continually substitute a more preferred option for a less preferred one, that person loses money. Of the 107 papers on violations of transitivity we found, not a single case showed that a person became a money pump. When looking at 1,036 articles on preference reversals – recall that attending to framing can lead to this phenomenon – we found that the question of cost was studied in only four articles, which found that arbitrage substantially reduced costs and that feedback diminished the frequency of reversals. Similarly, we identified 248 articles on framing and hundreds more on other deviations from logical rationality with little to no evidence that these "biases" make people less wealthy, less healthy, or less accurate in their beliefs. To ensure that no evidence had been overlooked, we asked approximately 1,000 researchers for studies that demonstrate costs, which none provided. Lack of evidence of costs is not the same as evidence for lack of costs. But the fact that so many studies failed to report evidence of costs suggests that either studies finding no evidence were not published or the assumption is considered self-evident.

The lack of evidence for the crucial assumption also leaves open the possibility of a political motivation, justifying governmental paternalism.

The Return of the Dichotomy: Intuition Versus Reason

In his paper "You Can't Play 20 Questions with Nature and Win," Allen Newell criticized the fact that psychological explanations are often conceived in the form of binary opposites, such as nature versus nurture, serial versus parallel processing, conscious versus unconscious, and intuitive versus analytic. Newell thought of these general dichotomies as the nadir of theorizing where, instead of achieving clarity, "matters simply become muddier and muddier as we go down through time."[69] Together with Herbert Simon, Newell instead set out to study the heuristic decision processes people use to make intelligent decisions. In spite of his critique, theorizing in terms of polarities (as opposed to heuristic processes) remains popular in cognitive psychology.

Recall the opposition between female intuition and male reason, as in Immanuel Kant's and Stanley Hall's view. That polarity has returned, now cleansed from its association with gender. Once more, intuition is opposed

[69] Newell (1973), pp. 288–289.

to reason, now in the form of an inferior intuitive System 1 and a superior logical System 2. I have no reason to assume that these similarities were by any means intentional. Yet, the similarity between the old view of women and the new System 1 has not escaped its proponents. Citing comedian Danny Kaye's joke "Her favorite position is beside herself, and her favorite sport is jumping to conclusions," Kahneman remarks, "I believe it offers an apt description of how System 1 functions."[70] Similarly, the fact that women score on average lower than men on the *cognitive reflection test*, a short test comprising three numeracy questions, has been attributed by decision scientist Shane Frederick to their supposedly higher reliance on the intuitive System 1, a reinstatement of the old stereotype about women.[71] Yet, leaping to the conclusion that the failure to answer mathematics questions results from attributes attached to System 1 is neither necessary nor supported by the evidence.[72] Consider the first question of the cognitive reflection test:

A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? _____cents

Most people appear to have forgotten the algebra they learned at school and answer "10 cents," although "5 cents" is the correct response. However, the wrong answers have been attributed not to the lack of mathematics, but to the fast, intuitive System 1 that gets the answer wrong. The correct answers are said to result from the slow System 2 after correcting the intuitive response.[73] Testing this interpretation would require a two-step procedure, where it is possible to separate the first intuitive response from the later one after deliberation. Such tests were conducted in a series of seven experiments:[74] People were given only a few seconds to give their immediate response (including the time for reading the problem), and they also had to memorize a pattern of dots they were shown before reading the problem in order to reduce the possibility of deliberate thinking to a minimum. After their intuitive response, participants were given as much time as desired to deliberate and provide a final response. On average (across all conditions that correspond to the test above), the intuitive response was correct 20.4 percent and the final response 26.8 percent of the time. This means that the majority of correct answers had already been made intuitively. Cases where deliberation

[70] Kahneman (2011a), p. 79. [71] Frederick (2005), p. 37.
[72] Bago & De Nays (2019); Easton (2018). [73] Frederick (2005); Kahneman (2011a).
[74] Bago & De Nays (2019).

improved the first response were relatively few. All in all, these experiments show that blaming intuition for the errors in the bat-and-ball problem is off the mark. The best explanation appears to be that most people simply cannot perform the mathematics; in fact, the performance of participants with this problem correlates substantially with their numeracy.

Despite Newell's critique, two-system theories that can "explain" all biases post hoc have become hugely popular. Again, the question of empirical evidence is rarely posed. A common feature of the various dual-system theories is that the polarity intuition versus reason is aligned with several other polarities, such as heuristic versus analytic and unconscious versus conscious. Given that these theories solely provide a list of general dichotomies, without specifying any testable model of the processes, they appear empty and unfalsifiable. But they actually imply two empirically testable claims: that intuition is opposed to reason, and that the poles of the dichotomies in each system are aligned with each other.

If, as assumed in two-systems theories, intuition is opposed to reason, they should be negatively correlated (people rely either on intuition or on reason). As mentioned in Chapter 1, however, a meta-analysis of 75 studies showed that measures of intuition and analysis are *not* negatively correlated (as opposites should be), but are instead independent.[75] Second, the alignment of the poles is not consistent with the evidence. Consider the alleged association between heuristic and unconscious in System 1. Every heuristic that I have studied to date can be used both consciously and unconsciously, meaning that alignment does not correspond to reality. Next, the association between statistical reasoning and consciousness in System 2 contradicts most theories in the cognitive and neurosciences, such as Bayesian theories of the brain, which assume that perception, memory, and other unconscious processes are based on statistical inferences.[76] Lastly, the association between intuitive, heuristic, and error-prone, on the one hand, and reason, logic, and rational, on the other, is called into question by the example of framing, which illustrates how intuition can lead to better medical outcomes than logical thinking, and by the empirically grounded fact that purely logical rationality can err as easily as intuition can. In general, there is a striking absence of empirical evidence for this historical polarity, which has reemerged in a new configuration.[77]

[75] Wang et al. (2017). [76] Chater & Oaksford (2008); Friston (2010).

[77] For a more detailed critique of dual-system theories see Keren & Schul (2009); Kruglanski & Gigerenzer (2011); Melnikoff & Bargh (2018).