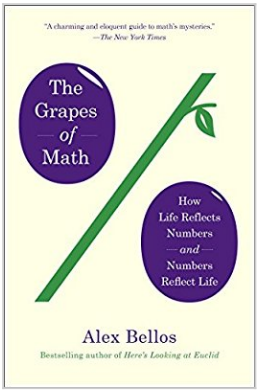

The Grapes of Math: How Life Reflects Numbers and Numbers Reflect Life

By Alex Bellos

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From triangles, rotations and power laws, to cones, curves and the dreaded calculus, Alex takes you on a journey of mathematical discovery with his signature wit and limitless enthusiasm. He sifts through over 30,000 survey submissions to uncover the world's favourite number, and meets a mathematician who looks for universes in his garage. He attends the World Mathematical Congress in India, and visits the engineer who designed the first roller-coaster loop.

Get hooked on math as Alex delves deep into humankind's turbulent relationship with numbers, and reveals how they have shaped the world we live in.

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The Grapes of Math: How Life Reflects Numbers and Numbers Reflect Life By Alex Bellos Bibliography

- Sales Rank: #322463 in eBooks
- Published on: 2014-06-10
- Released on: 2014-06-10
- Format: Kindle eBook

Editorial Review

Review
"Another sparkling romp through the world of numbers, with the inimitable Alex Bellos as your friendly, informed, and crystal-clear guide. A brilliant successor to Here's Looking at Euclid." (Ian Stewart, Professor of Mathematics, University of Warwick, and author of Visions of Infinity)

"Love the book! Fresh, fascinating and endlessly charming. A splendiferous book altogether." (Tim Harford, Financial Times, author of The Undercover Economist Strikes Back)

"See, numbers don't have to be scary!" (Evan Davis)

"Alex Bellos' *The Grapes of Math* is a delicious grab bag of mathematical miscellany that includes Benford's law, fractals, exponentials and imaginary numbers, the Game of Life, among many other goodies, all presented in a most entertaining style. Both fun and instructive." (John Allen Paulos is the author of several books including Innumeracy and A Mathematician Reads the Newspaper)

"Think of the best storyteller you know and the coolest teacher you ever had, and now you've got some idea of what Alex Bellos is like. His Grapes of Math taught me something new on every page. Better yet, it made me laugh and want to tell someone what I'd just read. Math has never been so much fun." (Steven Strogatz, professor of applied mathematics, Cornell University, and author, The Joy of x)

"[A] first-rate survey of the world of mathematics by a British practitioner of the art.... Great reading for the intellectually curious." (Kirkus)

"Channeling the spirit of Martin Gardner, the Guardian's math blogger Bellos (*Here's Looking at Euclid*) reveals—and revels in—the pleasures of mathematics, which he has dubbed 'the most playful of all intellectual disciplines.'… Bellos introduces fascinating characters, from the retired cabdriver in Tucson whose hobby is factoring prime numbers, to swashbuckling astronomer Tycho Brahe, who lost his nose in a duel over a math formula. Through intriguing characters, lively prose, and thoroughly accessible mathematics, Bellos deftly shows readers why math is so important, and why it can be so much fun." (Publishers Weekly (starred))

"An excellent book on what could be called 'mathematics appreciation'" (Library Journal)

"A charming and eloquent guide to math's mysteries…For its witty flourished, it's never shallow. Bellos doesn't shrink from delving into equations, which should delight aficionados who relish those kinds of details." (New York Times)

"Bellos' background as a storyteller makes *Grapes of Math* enjoyable whether you like math or not." (Metro)

"The book is appropriate for both the "math curious" and enthusiasts who wish to supplement their formal education." (Choice)

"The amiable Bellos is a people person, at heart, one who has compassion for those of us who feel a bit uncomfortable around a whole lot of numbers." (Boston Globe)

“Bellos's voice is warm and witty, calming the fears of the math-averse and providing a concise primer on long-forgotten principles of algebra and geometry.” (Shelf Awareness)

About the Author
Alex Bellos has a degree in Mathematics and Philosophy from Oxford University. Curator-in-residence at the Science Museum and the *Guardian*’s math blogger, he has worked in London and Rio de Janeiro, where he was the paper's unusually numerate foreign correspondent. In 2002 he wrote *Futebol*, a critically acclaimed book about Brazilian football, and in 2006 he ghostwrote Pelé's autobiography, which was a number one bestseller. *Here’s Looking at Euclid* was shortlisted for the BBC Samuel Johnson Prize and was a *Sunday Times* bestseller for more than four months.

The Grapes of Math

CHAPTER ONE

Every Number Tells a Story

Jerry Newport asked me to pick a four-digit number.

“2761,” I said.

“That’s 11 × 251,” he replied, reciting the numbers in one continuous, unhesitant flow.

“2762. That’s 2 × 1381.

“2763. That’s 3 × 3 × 307.

“2764. That’s 2 × 2 × 691.”

Jerry is a retired taxi driver from Tucson, Arizona, with Asperger’s syndrome. He has a ruddy complexion and small blue eyes, his large forehead sliced by a diagonal comb of dark blond hair. He likes birds as well as numbers, and when we met he was wearing a flowery red shirt with a parrot on it. We were sitting in his living room, together with a cockatoo, a dove, three parakeets and two cockatiels, which were also listening to, and occasionally repeating, our conversation.

As soon as Jerry sees a big number, he divides it up into prime numbers, which are those numbers—2, 3, 5, 7, 11 . . .—that can be divided only by themselves and 1. This habit made his former job driving cabs particularly enjoyable, since there was always a number on the license plate in front of him. When he lived in Santa Monica, where license numbers were four and five digits long, he would often visit the four-story car park of his local mall and not leave until he had worked through every plate.

In Tucson, however, car numbers are only three digits long. He barely glances at them now.

“If the number is more than four digits I’ll start to pay attention to it. If it’s four digits or less, it’s roadkill. It is!” he remonstrated. “Come on! Show me something new!”

Asperger's is a psychological disorder in which social awkwardness can coexist with extreme abilities, such as, in Jerry's case, an extraordinary talent for mental arithmetic. In 2010 he competed at the Mental Calculation World Cup in Germany having done no preparation. He won the overall title of Most Versatile Calculator, the only contestant to score full marks in the category where 19 five-digit numbers have to be decomposed into their constituent primes in ten minutes. No one else got even close.

Jerry's system for breaking down large numbers is to sieve out the prime numbers in ascending order, extracting a 2 if the number is even, extracting a 3 if it divides by three, a 5 if it divides by five, and so on.

He raised his voice to a yell: "Oh yeah, we're sievin', baby!" He started moving his body around: "We're onstage. Throw those numbers out, crowd, and we'll sieve 'em for ya! Yeah! Jerry and the Sievers!"

"I've got a pair of sievers," interrupted his wife, Mary, who was sitting on the sofa next to us. Mary, a musician and former Star Trek extra, also has Asperger's, which is much less common in women than it is in men. A marriage between two people with Asperger's is very rare, and their unconventional romance was turned into the 2005 Hollywood movie Mozart and the Whale.

Sometimes Jerry cannot extract any primes at all from a large number, which means the number is itself prime. When this happens it gives him a thrill: "If it's a prime number I've never found before, it's kinda like if you were looking for rocks, and you've found a new rock. Something like a diamond you can take home and put on your shelf."

He paused. "A new prime number—it's like having a new friend."

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The earliest words and symbols used for numbers date from about 5000 years ago in Sumer, a region in what is now Iraq. The Sumerians did not look far when coming up with names. The word for one, ges, also meant man, or erect phallus. The word for two, min, also meant woman, symbolic of the male being primary and the woman his complement, or perhaps describing a penis and a pair of breasts.

Initially, numbers served a practical purpose, like counting sheep and calculating taxes. Yet numbers also revealed abstract patterns, which made them objects of deep contemplation. Perhaps the earliest mathematical discovery was that numbers come in two types, even and odd: those that can be halved cleanly, such as 2, 4 and 6, and those that cannot, such as 1, 3 and 5. The Greek teacher Pythagoras, who lived in the sixth century BCE, echoed the Sumerian association of one with man and two with woman by proclaiming odd numbers masculine and even numbers feminine. Resistance to splitting in two, he argued, embodied strength, while susceptibility to splitting in two was a weakness. He gave a further arithmetical justification: odd was master over even, just as man is master over woman, because when you add an odd number to an even number, the answer remains odd.

Pythagoras is most famous for his theorem about triangles, which we will come to later. But his belief about number gender has dominated Western thought for more than two thousand years. Christianity embraced it within its creation myth: God created Adam first, and Eve second. One signifies unity, and two is the "sin which deviates from the First Good." For the medieval Church, odd numbers were stronger, better, more godly and luckier than the evens, and by Shakespeare's time, metaphysical beliefs about odd numbers were common: "They say there is divinity in odd numbers, either in nativity, chance or death," Falstaff declares in The Merry Wives of Windsor. These superstitions remain. Mystical numbers still tend to be odd, notably the "magic" three, the "lucky" seven, and the "unlucky" thirteen.

Shakespeare is also responsible for popularizing the modern meaning of “odd.” Originally, the word had only a numerical sense. It was used in phrases such as “odd man out,” the unpaired member of a group of three. But in Love’s Labour’s Lost, the farcical Spaniard Don Adriano de Armado is described as “too picked, too spruce, too affected, too odd, as it were.” Having one left over when divided by two has meant peculiar ever since.

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It is human nature to be sensitive to numerical patterns. These patterns provoke subjective responses, sometimes extreme ones, as we saw with Jerry Newport, but also more generally, leading to deeply held cultural associations. Oriental philosophy is based on an appreciation of the dualities in nature, symbolized by yin and yang, literally “shadow” and “light.” Yin is associated with passivity, femininity, the moon, misfortune and even numbers, and yang with their complements: aggressiveness, masculinity, the sun, good fortune and odd numbers. Again, we see a historic link between luck and oddness, and this link is especially strong in Japan, where, for example, it is customary to give three, five or seven items as a gift. Never four or six. In giving cash to newlyweds, the amounts ¥30,000, ¥50,000 and ¥100,000 are preferred, although ¥20,000 is acceptable, in which case the recommendation is to “odd things out” by dividing the value into one ¥10,000 and two ¥5,000 bills. The aesthetics of odd numbers also underpins the Japanese classical art of flower arranging, ikebana, which uses only odd numbers of items, an influence of the Buddhist belief that asymmetry reflects nature. A meal of Japanese haute cuisine, kaiseki, always comprises an odd number of dishes, and, just so kids get the message early on, the annual celebration of youthful good health is called the Seven-Five-Three festival, in which only children who are three, five and seven years old take part. The Japanese taste for odd numbers is so ingrained, wrote Professor Yutaka Nishiyama of the Osaka University of Economics, that when the government released a ¥2,000 note in 2000 no one ever used it.

(Number superstitions are stronger in East Asian countries than they are in the West. These countries also score higher in international tests of numeracy, indicating that strong mystical beliefs about numbers are not necessarily an impediment to learning arithmetical skills. Superstitions, in fact, may encourage a respect for numbers, and an intimacy and playfulness with them—just as mathematics does. The most widely held Asian number belief is based on a pun. Because the words for “four” in Japanese, Cantonese, Mandarin and Korean (shi, sei, si, sa) sound the same as the words in those languages for death, the number four is avoided when at all possible. Hotels across the region often do not have fourth floors, aeroplanes often do not have fourth rows and companies often do not release product lines with a 4 in the name. Indeed, the association of four with death is so strongly held that it has become a self-fulfilling prophecy: US records show that among Japanese and Chinese Americans, fatal heart attacks surge on the fourth of each month. Eight, however, is lucky, because the word in Chinese sounds like “prosperity.” The number 8 appears disproportionately often in retail prices in Chinese newspaper ads. Two deaths equal a prosperous life.)

In India too, odd numbers are seen as the most auspicious type of number. Is there any reason why in both the East and the West odd numbers are imbued with more spiritual significance than even ones? It may be related to the fact that our brains take longer to process odd numbers than evens, a phenomenon discovered by the psychologist Terence Hines of Pace University, which he calls the “odd effect.” In one experiment Hines displayed pairs of digits on a screen. Either the digits were both odd, such as 35, both even, such as 64, or one even and one odd, such as 27. He told respondents to press a button only when the digits were even-even or odd-odd. On average it took respondents about 20 percent longer to press the button when both digits were odd, and they made more mistakes. At first Hines did not believe his results, thinking there must be a flaw in his testing procedure, but the phenomenon showed up clearly in follow-up research. We feel differently toward odd numbers not just because of age-old cultural beliefs but because we think differently about them. They are literally more thought-provoking.

There is a linguistic clue to the odd effect, invisible to speakers of English, which is the only major European language to have unrelated words for odd and even. In French, German and Russian, for example, the words for even and odd are “even” and “not-even’: pair/impair, gerade/ungerade, and chyotny/nyechyotny. Evenness is an idea that precedes oddness. It is a simpler concept, easier to understand.

The cognitive gap between odd and even numbers has been the subject of other studies. James Wilkie and Galen Bodenhausen of Northwestern University decided to investigate whether there was any psychological basis to the ancient belief that odds are male and evens are female. They showed respondents randomly assigned pictures of the faces of young babies, each next to a three-digit number that was either odd-odd-odd or even-even-even, and asked them to guess the baby’s sex. This experiment sounds absurd, and it would have been forgotten had it not achieved a striking result: the choice of number had a significant effect. Respondents were about 10 percent more likely to say that a baby paired with odd numbers was a boy, than if the same baby was paired with even numbers. Wilkie and Bodenhausen concluded that the Pythagoreans, medieval Christians and Taoists were right. The ancient, cross-cultural belief that odds are associated with maleness and evens with femaleness was supported by the data. “It may indeed be a universal human tendency to project gendered meanings onto numbers,” they wrote. They were unable to explain, however, why odd is masculine and even is feminine, rather than vice versa.

Culture, language and psychology play a role in the way we understand mathematical patterns, as we have seen here with odd numbers, and as we will see shortly with other numerical cues. Numbers have a fixed mathematical meaning—they are abstract entities signifying quantity and order—yet they also tell other stories.

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The influential German theologian Hugh of Saint Victor (1096–1141) provided an early guide to numbers: ten represents “rectitude in faith,” nine, coming before ten, “defect among perfection,” and eleven, coming afterward, “transgression outside of measure.” If Hugh were alive today he would undoubtedly find lucrative employment at The Semiotic Alliance, one of the world’s leading semiotics agencies. I met its founder, Greg Rowland, in London. With a black-and-white T-shirt under his jacket, strong lines on his forehead and sharp eyes, he came across as a groovy university professor, although his habitat is not the library but the executive boardroom. Greg advises multinational companies on the symbolism of their brands, which involves the cultural associations of numbers. His clients include Unilever, Calvin Klein and KFC. The number eleven, for example, is an essential element of KFC’s corporate mythology: its signature dish is fried chicken seasoned with Colonel Sanders’s secret Original Recipe of eleven herbs and spices. “This is the key mystical use of the number eleven in commercial culture,” said Greg. The number represents transgression, he added, in this case an extra ingredient, one beyond the ordinary. “Eleven has just gone that one past ten. It has recognized that there is an order to things, and now it is exploring the distance beyond. Eleven is opening the door to the infinite, but it’s not going too far. It is . . . bourgeois rebellion at its most finite!” I asked if Colonel Sanders was therefore no different from the rocker in Spinal Tap whose amp went up to 11 so it could be louder than amps labeled to 10. Greg laughed: “Yes! But I actually believe it! I believe that 11 is more interesting than 10!”

The Spinal Tap–style extra 1, he added, is a common meme. A classic example is Levi’s 501 jeans. “This raises the expectation but doesn’t overplay it. It’s that extra little bit, and that is what Levi’s is always doing, or in its glory days always did: adding an extra little button here, or a new piece of sewing there. It really was just a 1. Levi’s is saying it’s not just 500, it’s one better than that, in the way that 502—two better—doesn’t work. There is that mystical added element, which stops it being as definable and reasonable as 500. For the big decimals it works best: the film 2001: A Space Odyssey, the 101 drum machine, Room 101. It wasn’t

Room 100—who'd be scared of that?"

Long before Levi's started making jeans, the significance of the extra 1 was an established part of Indian culture. Shagun is the tradition that gifts of money are always a round sum with one rupee added, such as Rs101, Rs501 or Rs100,001. Gift envelopes in wedding shops, for example, come with a one-rupee coin glued to them, so you don't forget it. While there is no single explanation for the practice—some say the 1 is a blessing, others that it represents the beginning of a new cycle—it is accepted that the symbolic value of the extra 1 is as important as the monetary value of the notes inside.

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Which brings me to an old family story. In the early twentieth century my grandfather was working on a new recipe for carbonated lemonade. He called it 4 Up. Consumers did not take to it, so he spent a few years developing it some more. His next launch, 5 Up, also failed. After another few years he released 6 Up, and guess what? It flopped, too. Grandad died, tragically, without knowing how close he came.

Yes, it's an old joke. But it contains a truth. In business, as in religion, a good number is fundamental. The number ten—"rectitude in faith"—strengthens faith in the anti-acne cream Oxy 10: "Ten is about balance, security, returning to the norm. It's the absolute decimal," said Greg. "There is no argument with 10, and that's what you want with spot things. You don't want Oxy 9, or Oxy 8 even. You certainly don't want Oxy 7 or 11 or 13 or 15. For a product like Oxy 10 you want certainty." I asked him if he thought the all-purpose lubricant WD-40 would have been as successful if it had been called WD-41. "WD-41 would not be reliable," he insisted. "WD-41 would have more stuff in it than you would want. It would have some extra bit in it, wouldn't it?" He thought aloud about other variants: "WD-10 would have binary function. Either it did something or it didn't. But then it is not WD-400 or 4000—you don't want to overdo it! WD-40 is not overclaiming. It is a simple, humble enhancement." According to company legend, the brand owes its name to the chemist Norm Larsen. He was trying to invent a liquid that would prevent corrosion, hence "Water Displacement" in the name. WD-40 was his fortieth attempt. It is impossible, of course, to know how well the product would have done had Larsen got the formula right on his forty-first try. Yet academic research corroborates Greg's semiotic evaluation: for household products, divisible numbers are more attractive to consumers than indivisible ones.

In 2011, Dan King of the National University of Singapore and Chris Janiszewski of the University of Florida demonstrated that an imaginary brand of anti-dandruff shampoo was better liked when it was called Zinc 24 than when it was called Zinc 31. The respondents preferred Zinc 24 so much that they were willing to pay ten percent more for it. King and Janiszewski argued that customers prefer 24 because they are more familiar with the number from their schooldays, when the lines $3 \times 8 = 24$ and $4 \times 6 = 24$ are drummed into pupils by rote. By comparison, 31 is a prime number and does not appear in any school multiplication table. The professors claimed that increased familiarity with 24 means we process the number more fluently, which gives us the feeling that we like it more. Our preference for 24 over 31, they argued, transfers to a preference for Zinc 24 over Zinc 31. Greg was not surprised when I told him of this research, but he had a more cultural take: "Zinc 24 fits our sense that even-numbered products bring us back to a sense of normalcy, to a sense of things as they should be," he said. "Odd numbers provide extra room for a bit of emotional negotiation, which is why there is more mysticism around them." And why, he added, we don't want them in our hair.

To reinforce their hypothesis that processing fluency increases brand preference, King and Janiszewski designed a follow-up experiment that subtly included a multiplication sum in the advertisement for a numbered brand. They first decided on the products, Solus 36 and Solus 37, two fictitious lines of the real contact lens brand Solus. They then created four ads: one for Solus 36, one for Solus 37, and one for each

product with the tagline “6 colors. 6 fits.” When there was no tagline, the participants preferred Solus 36 over Solus 37, as would be expected. But when the researchers included the tagline, Solus 36 increased in popularity and Solus 37 became even less popular than before. King and Janiszewski argued that our familiarity with 6, 6 and 36, from the six times table sum $6 \times 6 = 36$, increases our processing fluency of the numbers, just as the unfamiliarity of 6, 6 and 37, which are not arithmetically related, decreases it. The pleasure rush that comes from subconsciously recognizing a simple multiplication makes us feel good, they said, and we misattribute the buzz as satisfaction with the product. Companies would do well, they suggested, to include hidden sums in their ads.

Which package of contact lenses feels more desirable?

King and Janiszewski’s point is that we are always sensitive to whether a number is divisible or not, and this sensitivity influences our behavior. We are all a bit like Jerry Newport, the taxi driver from Tucson, who cannot see a number without dividing it up into primes. Splitting in two is the earliest and most natural type of division. The arithmetical pattern, therefore, that we are most sensitive to—and for which our cultural associations are the most deeply rooted—is the difference between the evens and the odds.

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Numbers were invented to describe precise amounts: three teeth, seven days, twelve goats. When quantities are large, however, we do not use numbers in a precise way. We approximate using a “round number” as a place mark. It is easier and more convenient. When I say, for example, that there were a hundred people at the market, I don’t mean that there were exactly one hundred people there. And when I say that the universe is 13.7 billion years old, I don’t mean exactly 13,700,000,000, I mean give or take a few hundred million years. Big numbers are understood approximately, small ones precisely, and these two systems interact uneasily. It is clearly nonsensical to say that next year the universe will be “13.7 billion and one” years old. It will remain 13.7 billion years old for the rest of our lives.

Round numbers usually end in zero. The word round is used because a round number represents the completion of a full counting cycle, not because zero is a circle. There are ten digits in our number system, so any combination of cycles will always be divisible by ten.

Because we are so used to using round numbers for big numbers, when we encounter a big number that is nonround—say, 754,156,293—it feels discrepant. Manoj Thomas, a psychologist at Cornell University, argues that our sense of unease with large, nonround numbers causes us to see these numbers as smaller than they are: “We tend to think that small numbers are more precise, so when we see a big number that is precise we instinctively assume it is less than it is.” The result, he claims, is that we will pay more for an expensive object if the price is nonround. In one of Thomas’s experiments, respondents viewed pictures of several houses together with their sale prices, which were randomly assigned either a round number, such as $390,000, or a slightly larger, precise one, such as $391,534. Asked whether they considered each price high or low, on average the respondents judged the precise prices to be lower than the round ones, even though the precise numbers were actually higher. Thomas and his collaborators argued that whatever other inferences the respondents were making about why the price was precise—such as that the seller had thought more carefully about it, and so the price was fairer—they still made the subconscious judgment that nonround numbers are smaller than round ones. A tip to readers selling their homes: if you want to make money, don’t end the price with a zero.

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Earlier we discussed the cultural connotations of adding 1 to a round number. The practice of subtracting 1 from a round number also conveys a potent message.

When we read a number, we are more influenced by the leftmost digit than by the rightmost, since that is the order in which we read, and process, them. The number 799 feels significantly less than 800 because we see the former as 7-something and the latter as 8-something, whereas 798 feels pretty much like 799. Since the nineteenth century, shopkeepers have taken advantage of this trick by choosing prices ending in a 9, to give the impression that a product is cheaper than it is. Surveys show that anything between a third and two-thirds of all retail prices now end in a 9.

Though we are all seasoned shoppers, we are still fooled. In 2008, researchers at the University of Southern Brittany monitored a local pizza restaurant that was serving five types of pizza at €8 each. When one of the pizzas was reduced in price to €7.99, its share of sales rose from a third of the total to a half. Dropping the price by one cent, an insignificant amount in monetary terms, was enough to influence customers' decisions dramatically.

Our response to prices ending in 9, however, is subject to more complex influences than a bias toward the leftmost digit. A price ending in 9 feels like a bargain, even when it isn't. Eric Anderson of the University of Chicago and Duncan Simester of MIT arranged for the same dress to be priced at $34, $39 and $44 in three otherwise identical mail order catalogues. The dress sold best at $39, rather than the cheaper price of $34. Similar results have been found in other studies: the 9-ending is a cue that the item has been discounted and is therefore a good deal. But the association of 9 with bargains can also mean that a 9-priced product looks cheap, or can give the impression that the seller is somehow manipulating you. An upmarket restaurant, for example, would never dream of pricing a main course at, say, $32.99. Nor would you trust a therapist who charged $99.99 a session. The prices would be $33 and $100, which feel both classier and more honest. Our response to the number 9 is conditioned by a mixture of cultural and psychological factors. Numbers are not impartial and straightforward; they have baggage.

Shopkeepers have other reasons for using prices that end in a 9, or, for that matter, an 8. Tests show that prices ending in 8 and 9 are much harder to recall than prices ending in 0 and 5, since the brain takes longer to store and process them. If you don't want your customers to remember a price, to prevent them from comparing prices, then use an 8- or 9-ending. Conversely, if you do want a customer to remember a price, perhaps to reinforce that it is cheaper than rival products, label it $5 and not $4.98. Traders, in fact, use an array of psychological number tricks to reduce price awareness. For example, a Cornell University study showed that by leaving the currency sign off a menu—so that the price of a dish was listed as 20 rather than $20—a New York restaurant increased average spending per customer by eight percent. The "$" reminds us of the pain of paying. Another clever menu strategy is to show the prices immediately after the description of each dish, rather than listing them in a column, since listing prices facilitates price comparison. You want to encourage diners to order what they want, whatever the price, rather than reminding them which dish is most expensive.

Perhaps the most blatant use of number psychology in retail, however, is the display of absurdly expensive items to create an artificial benchmark. The $100,000 car in the showroom and the $10,000 pair of shoes in the shop window are there not because the manager thinks they will sell, but as decoys to make the also-expensive $50,000 car and $5,000 shoes look cheap. Supermarkets use similar strategies. We are surprisingly susceptible to number cues when it comes to making decisions, and not just when shopping. In one study, 52 German judges read a description of a woman caught shoplifting, and then rolled a pair of dice, loaded to

land either on 1 and 2, or on 3 and 6. Once the dice were rolled, the judges were asked to state whether they would sentence the woman to more or fewer months in prison than the sum of the numbers on the dice, and then to specify the exact sentence. The judges who rolled 3 gave her five months on average, while the judges who rolled 9 gave her eight. The judges were experienced professionals, yet the mere suggestion of a number with no connection to the case determined the length of sentence.

Roast fillet of smoked haddock with warm potato salad and crispy onions 17.50
Cream of mushroom soup with truffle chantilly 15.50
Warm organic Gloucestershire chicken ballotine stuffed with herbed couscous and leek fondue 18.20

Roast fillet of smoked haddock with warm potato salad and crispy onions

$17.50

Cream of mushroom soup with truffle chantilly

$15.50

Warm organic Gloucestershire chicken ballotine stuffed with herbed couscous and leek fondue

$18.20

Good menu, bad menu.

If earnest German judges can be swayed by an irrelevant random number, think about the rest of us. Every time we perceive a number it primes us, influencing our behavior in ways we are not always aware of and cannot always control.

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Another response to numbers is affection. After counting, calculating and quantifying with our numerical tools it is common to develop feelings for them. Jerry Newport, for example, loves some numbers like friends. I had not realized the depth of our collective number love, however, until I conducted an online experiment, asking members of the public to nominate their favorite numbers and explain their choices. I was taken aback not only by the level of interest—more than 30,000 people took part in the first few weeks—but also by the variety and tenderness of the submissions: 2, because the respondent has two piercings; 6, because the sixth track on the respondent's favorite albums is always the best song; 7.07, since the respondent used to always wake up at 7:07am, and once her shopping added up to $7.07 in front of the cute cashier at her local shop; 17, because that's how many minutes the respondent takes to cook rice; 24, because the respondent sleeps with her left leg kicked out like a 4 and her boyfriend sleeps like a 2 on his side; 73, known to fans of The Big Bang Theory as the "Chuck Norris of numbers," because the main character, Sheldon Cooper, points out that it is the 21st prime number, and its mirror 37 is the 12th; 83, because it sounds good to exaggerate with, as in "I must have done it 83 times!"; 101, because it is the lowest whole number with an "a" in it; 120, because it is divisible by 2, 3, 4, 5, 6, 8 and 10, providing the respondent with sufficient numbers to count up and down to get to sleep; 159, because it is the diagonal on a phone keyboard; 18,912, because its cadence makes it "the most beautiful sounding number in the world'; and 142,857, the phoenix number, because its first six multiples are well-ordered numerical anagrams of itself:

142857142857

142857 × 1 =

142857

142857 × 2 =

285714

142857 × 3 =

428571

142857 × 4 =

571428

142857 × 5 =

714285

142857 × 6 =

857142

142857 × 7 =

999999

“Having a favorite number means that you get a little buzz every time you happen to be sitting in seat 53 on a train, or notice that the time is 09:53,” wrote one respondent. “I can’t think of a reason not to have a favorite number.”

—

With the caveat that the survey was voluntary and self-selecting, a bit of fun rather than rigorously undertaken academic research, the data revealed fascinating patterns in favorite number choices.

First, the span of our number hug is huge: 1123 individual numbers from 30,025 submissions. There were votes for every whole number between 1 and 100, and 472 of the numbers between 1 and 1000. The lowest whole number that failed to pick up any votes was 110. Surely the world’s least-loved number?

Here’s the final table:

Position

Number

Percentage

1

7

9.7%

2

3

7.5%

3

8

6.7%

4

4

5.6%

5

5

5.1%

6

13

5.0%

7

9

4.8%

8

6

3.4%

9

2

3.4%

10

11

2.9%

11

42

2.8%

12

17

2.7%

13

23

2.3%

14

12

2.2%

15

27

1.9%

16

22

1.5%

17

21

1.4%

18

π

1.4%

19

14

1.3%

20

24

1.2%

21

1

1.2%

22

16

1.2%

23

10

1.2%

24

37

1.0%

25

0

1.0%

26

19

0.9%

27

18

0.8%

28

e

0.7%

29

28

0.7%

30

69

0.6%

Roughly speaking, we like single digits best, and the bigger a number is, the less we like it. The table also reveals a shocking indifference toward round numbers. The numbers from two to nine are all in the top ten, but ten is way down in 23rd place, twenty is in 50th and thirty in 69th. Ten is the cornerstone of the decimal system, yet it is not very lovable, possibly because it is always prostituting itself as an approximation.

Some numbers are chosen for their numerical properties, such as the phoenix number on p. 14, and also the constants π and e, which we will look at much more closely later in this book. Usually, however, a number is chosen for a personal reason, most commonly because it is the day of the month we were born. Yet the distinction between a numerical and a personal reason is not clear-cut, since there are some numbers that are rarely chosen as favorites even if the person was born on that day. For example, if you were born on the 10th of the month, you are six times less likely to choose 10 as your favorite number than you are likely to choose 7 if you were born on the 7th of the month. If you were born on the 30th you are forty times less likely to choose 30. Some numbers evidently make better favorites than others. (One of the reasons I became so curious about favorite numbers is because I don't have one, and I couldn't quite believe that so many other people felt so passionately about them. Now I blame my lack of a favorite number on the fact that I was not

born between the 2nd and the 9th of the month.)

—

The historic tendency of odd numbers to attract more attention than even numbers is reflected in the survey. Among the submissions for numbers between 1 and 1000, the ratio of those preferring odds over evens is about 60:40. The table also shows that Douglas Adams's joke that 42 is the answer to life, the universe and everything is still hilarious more than three decades after he first made it. (His gag plays on our collective feelings about numbers too: 42 works because it is so bland. It would not be as funny had he chosen, say, 41, which is odd and prime.) The appearance of 69 shows that juvenile humor cannot be eliminated from internet polls.

—

Seven came first overall. It was also the unanimous choice irrespective of the age, gender and mathematical ability of the respondent, which is hardly a surprise. Seven has been the most culturally feted number for as long as we know. Wonders of the world, deadly sins, ages of man, pillars of wisdom, brides for brothers, seas, samurai and dwarfs all come in sevens. Babylonian ziggurats were built with seven stories, the Egyptians spoke of the seven gates of the netherworld, the Vedic sun god has seven horses, and Muslims must walk round the Kaaba seven times during the hajj. Even now, the fundamental rhythm of our lives is a cycle of seven: the number of days in a week.

The very first thing humans counted was time. We carved notches on sticks and daubed splotches on rocks to mark the passing of days. Our first calendars were tied to astronomical phenomena, such as the new moon, which meant that the number of days in each calendar cycle varied, in the case of the new moon between 29 and 30 days, since the exact length of a lunar cycle is 29.53 days. In the middle of the first millennium BCE, however, the Jews introduced a new system. They decreed that the Sabbath come every seven days ad infinitum, irrespective of planetary positions. The continuous seven-day cycle was a significant step forward for humanity. It emancipated us from consistent compliance with Nature, placing numerical regularity at the heart of religious practice and social organization, and since then the seven-day week has become the world's longest-running uninterrupted calendrical tradition.

But why seven days in the week? Seven was already the most mystical of numbers by the time the Jews declared that God took six days to make the world, and rested the day after. Earlier peoples had also used seven-day periods in their calendars, although never repeated in an endless loop. The most commonly accepted explanation for the predominance of seven in religious contexts is that the ancients observed seven planets in the sky: the Sun, the Moon, Venus, Mercury, Mars, Jupiter and Saturn. Indeed, the names Saturday, Sunday and Monday come from the planets, although the association of planets with days dates from Hellenic times, centuries after the seven-day week had been introduced. It is ironic that the Jewish week—the first calendar system to sever the link between the planetary orbits and the counting of days—ended up with its seven days named after the planets. Perhaps the astrological connection made the week more resilient to competing systems. Some historians argue that a period of seven days was originally chosen because it is roughly a quarter of a 29.53-day lunar month. But if divisibility were the issue a more accurate calendar would have had five weeks of six days, six weeks of five days, or even three weeks of ten days.

The Egyptians used the following hieroglyph for seven,  , the human head, which suggests another possible reason for the number's symbolic importance. There are seven orifices in the head: the ears, eyes, nostrils and mouth. Human physiology provides other explanations too. Six days might be the optimal length of time

to work before you need a day's rest, or seven might be the most appropriate number for our working memory: the number of things the average person can hold in his or her head simultaneously is seven, plus or minus two.

I'm not convinced by any of the reasons above, even if they are happy coincidences. Seven is special not because of planets, orbits or orifices, but because of arithmetic. Seven is unique among the first ten numbers because it is the only number that cannot be multiplied or divided within the group. When 1, 2, 3, 4 and 5 are doubled the answer is less than or equal to ten. The numbers 6, 8 and 10 can be halved and 9 is divisible by three. Of the numbers we can count on our fingers, only 7 stands alone: it neither produces nor is produced. Of course the number feels special. It is!

Psychologists have studied the uniqueness of seven for decades. When people are asked to think of a digit off the top of their heads, they are most likely to think of a 7. When asked to think of a number between 1 and 20, the majority will think of 17. Such is the subconscious drive toward numbers ending in 7 that it is the basis of a classic trick, in which the magician asks a volunteer to think of a two-digit odd number between 1 and 50 whose digits are different (so 15 is permitted but 11 is not), and correctly predicts that he or she is thinking of . . . the number in the footnote. Have a guess before you look.I The psychologists Michael Kubovy and Joseph Psotka argued that when asked to generate a random digit, participants will eliminate numbers that seem too unspontaneous—the even numbers, the multiples of three, and the numbers 0, 1 and 5 since they fall either at the beginning or in the middle of the sequence. Seven is the oddest man out—noneven, nonround and prime.

A favorite number reflects one's uniqueness. You can't do better than seven, the ultimate outsider.

—

Numbers express quantities. In the submissions to my online survey, however, respondents frequently attributed qualities to them. Noticeably, colors. The number that was most commonly described as having its own color was four (52 votes), which most respondents (17) said was blue. Seven was next (28 votes), which most respondents (9) said was green, and in third place came five (27 votes), which most respondents (9) said was red. Seeing colors in numbers is a manifestation of synesthesia, a condition in which certain concepts can trigger incongruous responses, and which is thought to be the result of atypical connections being made between parts of the brain.

In the survey, numbers were also labeled "warm," "crisp," "chagrined," "peaceful," "overconfident," "juicy," "quiet" and "raw." Taken individually, the descriptions are absurd, yet together they paint a surprisingly coherent picture of number personalities. Below is a list of the numbers from one to thirteen, together with words used to describe them taken from the survey responses.

One

Independent, strong, honest, brave, straightforward, pioneering, lonely.

Two

Cautious, wise, pretty, fragile, open, sympathetic, quiet, clean, flexible.

Three

Dynamic, warm, friendly, extrovert, opulent, soft, relaxed, pretentious.

Four

Laid-back, rogue, solid, reliable, versatile, down-to-earth, personable.

Five

Balanced, central, cute, fat, dominant but not too much so, happy.

Six

Upbeat, sexy, supple, soft, strong, brave, genuine, courageous, humble.

Seven

Magical, unalterable, intelligent, awkward, overconfident, masculine.

Eight

Soft, feminine, kind, sensible, fat, solid, sensual, huggable, capable.

Nine

Quiet, unobtrusive, deadly, genderless, professional, soft, forgiving.

Ten

Practical, logical, tidy, reassuring, honest, sturdy, innocent, sober.

Eleven

Duplicitous, onomatopoeic, noble, wise, homey, bold, sturdy, sleek.

Twelve

Malleable, heroic, imperial, oaken, easygoing, nonconfrontational.

Thirteen

Gawky, transitional, creative, honest, enigmatic, unliked, dark horse.

You don’t need to be a Hollywood screenwriter to spot that Mr. One would make a great romantic hero, and Miss Two a classic leading lady. The list is nonsensical, yet it makes sense. The association of one with male characteristics, and two with female ones, also remains deeply ingrained.

—

Since the favorite-number survey was voluntary, it was biased toward those people who already had clear

emotional attachments to numbers. But what about everyone else?

Take the number 44.

Do you like it? Do you dislike it? Do you remain unmoved?

Dan King and Chris Janiszewski, the professors we met earlier in our discussion of the shampoo Zinc 24, conducted an experiment in which all participants indicated whether they liked, disliked or felt neutral about every number from 1 to 100. The numbers were ranked from most liked to least liked.

The responses demonstrated that this was not a ridiculous question to ask. Our liking of numbers follows clear patterns, as shown below in a “heat map” in which the numbers from 1 to 100 are represented by squares. (The top row of each grid contains the numbers 1 to 10, the second row the numbers 11 to 20, and so on.) The numbers marked with black squares represent those that are “most liked” (the top twenty in the rankings), the white squares are the “least liked” (the bottom twenty) and the squares in shades of gray are the numbers ranked in between.

The heat map shows conspicuous patches of order. Black squares are mostly positioned at the top of the grid, showing on average that low numbers are liked best. The left-sloping diagonal through the center reveals that two-digit numbers where both digits are the same are also attractive. We like patterns. Most strikingly, however, four white columns display the unpopularity of numbers ending in 1, 3, 7 and 9. King and Janiszewski’s opinion, as mentioned previously, is that numbers that are the answers to common arithmetical problems, such as numbers that appear in the times tables, are more familiar, more fluently processed and hence more liked. The even numbers and numbers ending in 5 are always divisible, but the numbers ending in 1, 3, 7 and 9 are often not.

In a similar experiment, Marisca Milikowski of the University of Amsterdam asked participants to rank each number between 1 and 100 on three scales: between good and bad, between heavy and light, and between excitable and calm. Again, when asked to project nonmathematical meanings onto numbers, our responses are remarkably coherent. I have translated the results into the heat maps opposite.

The patterns are pronounced. The white columns in the “Good” grid show that numbers ending in 3, 7 and 9 are the least good, which is perhaps not surprising, since we saw previously that we like them least. In the “Heavy” grid, the black has sunk to the bottom, indicating that the larger a number is, the heavier we interpret it to be. The pattern in the “Excitable” grid is not obvious at first, but upon examination the columns ending in an odd number are darker on average than those ending in an even number. Odds are excitable, and evens calm. We find it easy to project nonmathematical meanings onto numbers, and these meanings reflect numerical properties, most clearly size and divisibility.

The bottom left grid is a heat map of number rankings from the favorite number survey, with the top 20 favorites in black, and so on. The bottom right grid displays the results of another online survey I set up, in which participants chose a number at random between 1 and 100. The 20 most popular nominations are in black. Interestingly, these two maps resemble each other: when asked to think about which number we like best, and when asked to think of the first number that comes into our heads, we tend to nominate the same candidates. Counterintuitively, our favorite numbers are generally not the numbers that we like best or think are most good. Like is very different from love.

—

When I first saw the heat maps, I instantly thought of Jerry Newport, the world champion mental calculator and former taxi driver I visited in Arizona. Jerry told me that when he comes face-to-face with a four- or five-digit number, he spontaneously “sieves” out the prime numbers. In other words, he initially calculates if it is possible to divide the number by 2, and then by 3, and then by 5, 7, 11, and so on upward, in order to decompose it into its unique prime divisors.

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