

## Oliver Sacks and the Amazing Twins

(originally posted on my blog for Discover Magazine's website, 2/15/13)

The mystery of whether there is a natural resonance between music and our brains, as I mentioned in a post last week, brings up an even deeper question: whether mathematics itself is neurologically innate, giving the mind (or some minds) direct access to the structure of the universe. Thinking about that recently led me back to one of Oliver Sack's most astonishing essays. It appeared in his collection *The Man Who Mistook His Wife for a Hat*, and is about two twins, idiot savants who appeared to have an almost supernatural ability to quickly tell if a number is prime.

Prime numbers are those that cannot be broken down into factors — smaller numbers that can be multiplied together to produce the larger one. They have been described as the atoms of the number system. 11 and 13 are obviously prime while 12 and 14 are not. But with larger numbers our brains are quickly flummoxed. Is 7244985277 prime? I just typed the digits by twitching my fingers along the top row of my keyboard. To test the number by hand I would have to start at the beginning of the number system and begin trying out the possible divisors.

There are shortcuts to avoid testing every single one. We know 2 can't be a factor since 7244985277, like all primes, is odd. For the same reason we can rule out all even factors. And you only have to test factors up to the square root of a number. (The factors of 100 are 2 x 50, 4 x 25, 5 x 20, and 10 x 10. Testing beyond 10 would be redundant.)

There are ways to pare down the calculations even further. Numbers ending in 5 can't be prime, and there are tricks for seeing if a number is divisible by 3, 7, or other small factors. Mathematicians have come up with other more sophisticated algorithms. But that still leaves long nights of mental drudgery. It took until the late 1800s for mathematicians to dig out a prime as large as 39 digits — and another half a century to get up to 44 digits.

Now I can check my number with the online tool Primomatic (it can be broken into 2659 and 2724703). Testing by hand a number that long could take anywhere from hours to months of arithmetic.

In Sacks's account, the twins — who were variously diagnosed as autistic, psychotic, or severely retarded — are said to have been able to perceive within minutes whether a 20-digit number, twice as long as the one I came up with, was prime.

It makes for a wonderful story with allusions to Borges and the great neuropsychologist Alexander Luria. Sacks tells how he met the twins in 1966 at a state mental hospital. With IQs of 60 they could barely do simple arithmetic, he reports, but they were already known as calendrical calculators. Given a date far in the future they could quickly tell you what day of the week it would fall on.

Their eyes move and fix in a peculiar way as they do this — as if they were unrolling, or scrutinizing, an inner landscape, a mental calendar.

Eerie as it seems, there are calculational tricks for doing that, though Sacks insists they were beyond the ability of the twins. But what he goes on to describe — and he was apparently the only one ever to witness this — is far more amazing, defying what is currently understood about the nature of computation and the brain.

One day he came upon the brothers sitting together in a corner “with a mysterious, secret smile on their faces.” One twin would say a long number and the other would nod and smile in appreciation. Then he would offer an equally long number of his own. “They looked, at first, like two connoisseurs wine-tasting, sharing rare tastes, rare appreciations.”

As this point they were trading six-digit numbers. Sacks took notes, and when he got home he looked the numbers up in a book of mathematical tables and found that they were primes. Though the twins had the ability to remember and repeat long streams of numbers, there was no reason to believe that they had somehow gained access to a table of primes. They appeared, Sacks suggests, to be somehow grokking the numbers from some Platonic realm where numerical truths reside.

Sacks brought the book with him the next day to the hospital, and when he found the brothers playing their game he sidled up and circumspectly offered his own contribution, an eight-digit number from the table of primes.

They both turned toward me, then suddenly became still, with a look of intense concentration and perhaps wonder on their faces. There was a long pause—the longest I had ever known them to make, it must have lasted a half-minute or more—and then suddenly, simultaneously, they both broke into smiles.

They had, after some unimaginable internal process or testing, suddenly seen my own eight-digit number as a prime—and this was manifestly a great joy, a double joy, to them: first because I had introduced a delightful new plaything, a prime of an order they had never previously encountered; and, second, because it was evident that I had seen what they were doing, that I liked it, that I admired it, and that I could join in myself.

They drew apart slightly, making room for me, a new number playmate, a third in their world. . . .

After several minutes of quiet one of the twins came up with a nine-digit number, and the other thought for a while and matched it with his own. Sacks looked in his book and offered a 10-digit prime.

There was again, and for still longer, a wondering, still silence; and then John, after a prodigious internal contemplation, brought out a twelve-figure number.

At this point Sacks could no longer check their work. His book, he writes, only went as high as 10-digits. But the twins kept on going and after an hour they were exchanging 20-digit numbers, also untestable.

And — this is the part of the story that drives me crazy — Sacks apparently didn’t write the numbers down.

A Dutch mathematician and skeptic, Pepijn van Erp, has suggested how, with a bit of luck, the twins might have chanced upon the six-digit primes that first drew Sacks’s attention. But why, he wonders, didn’t Sacks think to test the twins’ powers by slipping in “fake primes” — numbers like the one I clacked out above that look like they might be prime but are not? Would they have smiled in wonder at those too? And if only Sacks had called on some mathematicians and psychologists to help him discreetly perform more tests. Instead he seems to have put the matter aside until he wrote about it almost 20 years later.

By that time the twins had long been separated and moved to halfway houses. They lost their numerical powers, and there was no way to check the story. That left Sacks free to cling to his

romantic interpretation: “The twins seem to employ a direct cognition—like angels,” he wrote. “They see, directly, a universe and heaven of numbers.” – George Johnson, [talaya.net](http://talaya.net)

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### Idiot Savants and Prime Numbers (3/4/13)

In the week since I wrote about Oliver Sacks and the idiot savant twins, I’ve been catching up with Season 2 of “Touch,” the TV series about an autistic boy named Jake who has an inexplicable ability to commune with a secret world of numbers — a buried skein of mathematics in which the Golden Mean, the fibonacci sequence, the genetic code, and the Kabbalah are all mysteriously connected. Jungian synchronicity, quantum entanglement, chaos theory — all turn out to be manifestations of an underlying order in which everything that perplexes us ultimately makes sense.

It is the dream of both mystics and scientists, and I had wondered shortly after the show first began how the conceit was going to be sustained through more than a few episodes. The connecting thread has turned out to be a conspiracy by a shadowy corporation called AsterCorp — as secretive and powerful as Massive Dynamic, purveyors of the mind-enhancing medicine Cortexiphan in “Fringe” — to kidnap Jake and others like him in their attempt to control the world. Or the universe. It is too soon to tell.

Dr. Sacks’s twins, with their power to see, hear, smell — somehow sense within minutes if a number was prime — would also have been on AsterCorp’s wish list.

Something keeps pulling me back to Sacks’s story. That is how enchanting a writer he is. (His memoir, *Uncle Tungsten*, is my favorite of his books.) There are plenty of accounts in the psychiatric literature of amazing human calculators and mnemonists. Sacks describes some famous cases in his essay. But what he thought he saw in the twins went far beyond that. Somehow, as Sacks described it, they could recognize that a number is prime in the way that one might recognize a face. Something on the surface of 3334401341 told them it was prime while 3334401343 was not.

For the rest of us, the only way is to start dividing. I mentioned in my earlier post that you don’t have to try every possible divisor smaller than the number you are considering. You needn’t test numbers larger than the square root, and you can ignore any factors that are even or that end in 5. But for a 10-digit number that still leaves thousands of calculations. A 20-digit number would involve billions of them. When computers and networks of computers are harnessed to test big primes the machines are programmed with sophisticated algorithms that exploit as many shortcuts as possible. (If you have a list of all the smaller primes already stored in memory, you only have to divide by those, skipping over the composites.) But the process still comes down to an enormous amount of number crunching.

Sacks was not suggesting that the twins were human computers, rapidly carrying out calculations — millions per second, one after one, or all at once in parallel. Either would be an astounding feat. He ventured instead that they were “serene contemplators of number,” endowed with “a harmonic sensibility, perhaps allied to that of music.” He called it Pythagorean. They

could tell that a number had the ring of a prime the way someone might recognize a musical chord.

What the twins were doing, Sacks proposed, could not be broken down into a procedure, no matter how many steps or subroutines were involved. Their talent was non-algorithmic. It was, in other words, something beyond what any conceivable computer — electronic or biological, serial or parallel, analog or digital — can possibly do. A computer might do it faster, but not in the twins' special way.

And that is as good as suggesting that their powers would be beyond the realm of the material world, somewhere science cannot reach. — George Johnson, [talaya.net](http://talaya.net)

update:

I've qualified my final sentence a bit. A reader has suggested that something that is non-algorithmic may not necessarily be beyond the material world — a prelude to what could be a fascinating discussion of the Turing-Church-Deutsch hypothesis, which holds that “every finitely realizable physical system can be perfectly simulated by a universal model computing machine operating by finite means.” That would include quantum computers. Please stay tuned for more.

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### The Case of the Quantum Brain (3/7/13)

There is another, rather mind-blowing explanation for how Oliver Sacks's twins, in their contemplation of prime numbers, might perform billions of computations in their heads: their brains were quantum computers.

Consider, in a heroic suspension of disbelief, what that would mean. In an ordinary computer the elements that are manipulating the ones and zeroes of binary code are transistors or some kind of electronic switch. Tiny as they are — microscopic — each is still made of a huge number of atoms. They behave according to the crisp, hard-edged laws of classical mechanics.

Calculations in a quantum computer are performed instead by single atoms or single subatomic particles. A different, more fundamental kind of physics kicks in. All of the divisions required to test the primeness of a long number could be carried out simultaneously in quantum superposition (like Schrodinger's Cats in various states of oneness and zeroness, dead and alive). The quantum counters — the qubits — are connected not with wires but through the phenomenon called quantum entanglement (Einstein's “spooky action at a distance.”) And they are capable of factoring numbers (or so it has been demonstrated on paper) far faster than the most powerful digital machines. They can take a shortcut through time, which was the name of a book I wrote about the subject.

So, venturing further out on this limb (which is about to break any minute and plunge into the abyss below), let's suppose that the twins weren't calculating with their neurons, nature's slow, squishy version of computer chips, but with the individual atoms from which the neurons are made.

Or, more specifically, with microtubules — units that make up the cytoskeleton of neurons and other cells. Stuart Hameroff at the University of Arizona has developed an elaborate theory in which electrons in this microscopic scaffolding can become entangled with electrons in the scaffolding of other neurons. The result would be a biological quantum computer. The theoretical physicist Roger Penrose, in three long books, lays out a forbiddingly complex argument in which quantum computation gives rise to human consciousness and the ability to commune with the mathematical purity of the Platonic realm. This is all part of a small school of thought that rejects the idea that the brain works by processing information — that what it does instead is noncomputational, as Sacks thought was true with the twins.

Hardly anyone else believes this. The reason we don't see spooky superpositions out on the street is because the slightest jostling — one atom vibrating against another — will corrupt the quantum purity and cause the calculation to collapse. That is why the experimental quantum computers developed in physics labs operate only at temperatures near absolute zero.

And anyway — why would the twins be able to tap this deep well and perform great mathematical feats closed off to the rest of us?

There is a whole shelf of books on the notion that the brain is doing something beyond computation. The philosopher Colin McGinn gives a taste of this thinking in a review of Ray Kurzweil's new book, *How to Create a Mind*, in the current *New York Review of Books*. I'll be writing more about these things, on and off over the next year, but for now let's consider a far likelier explanation for Sacks's extraordinary report.

The twins were widely known for happily remembering and reciting long numbers. Maybe, unbeknown to Sacks, someone taught them a few six-digit primes. Or, as Pepijn van Erp suggests, it is not so unlikely that the brothers, in their numerical jousting, might have stumbled across a few primes by chance. When Sacks gave them a 10-digit prime they were simply marveling at its length not its nature, and then they matched it with some equally long number of their own.

Sacks never directly says — though he strongly implies it — that he checked the number in his book. And doubts have been raised (in a letter to *The Journal of Autism and Developmental Disorders*) about whether such a book even existed then. As the twins kept topping each other with longer and longer numbers there was, as Sacks writes, no way to check. And he didn't save the information or consult someone with access to a computer that could have run a test. He had already convinced himself that his subjects had to be generating primes. So he moved on to the next neurological oddity that caught his attention.

Just last month (this was also in the *NYRB*) Sacks reflected on the fallibility of memory. He was describing a conversation he had with his older brother after the publication of *Uncle Tungsten*. In the memoir Sacks described a frightening experience from his childhood — when a German fire bomb landed in the back yard of the family home in London. But as he learned from his brother, they both had been away at boarding school when that happened. He had learned about the incident in a letter from his father. “A very vivid, dramatic letter,” his brother told him. “You were enthralled by it.”

Sacks was dumbfounded. “Although I now know, intellectually, that this memory was ‘false,’ it still seems to me as real, as intensely my own, as before.”

This is a prelude to a wonderful essay about cryptomnesia, embracing stories about Coleridge, Helen Keller, Ronald Reagan, George Harrison, Sigmund Freud, and the maverick ideas of neuroscientist Gerald Edelman (another *NYRB* regular). Sacks is a writer with a beautiful mind. He closes with his thoughts on memories not as recordings but as creations and re-creations — rough, malleable versions of the past.

“We, as human beings, are landed with memory systems that have fallibilities, frailties, and imperfections — but also great flexibility and creativity,” Sacks writes. What we believe and honestly report as fact can turn out to be artful embellishment. Stories too good to check.

– George Johnson, [talaya.net](http://talaya.net)