

Islands of Genius

James W. Wright

Presented to the SpheX Club of Lynchburg

November 17, 2022

Last April I read a story in the Washington Post about Vaughn Smith, a 46-year-old Washington, D.C. man, a high school graduate, who works for his brother's carpet cleaning business. The Post reporter had been told by a friend of Smith's that Smith had an unusual ability that he didn't tell people about: almost completely self-taught, he speaks and writes eight languages without difficulty; he can carry on deep conversations and can read and write another six, and can have simple conversations about many topics in an additional ten languages. He has a more basic understanding of yet another 17 languages. Let's listen to Vaughn speak—pay attention to the subtitles. He may be the most prodigious polyglot on the planet. Vaughn Smith got me to thinking about people who have extraordinary abilities.

Benjamin Rush, Philadelphia physician, friend of Thomas Jefferson, signer of the Declaration of Independence, and regarded by some as the Father of American Psychiatry, in 1789 described the

case of Thomas Fuller, who was brought from west Africa as a slave at age 14, and was widely known in his time as Negro Tom or the Virginia

Calculator. Fuller could neither read nor write but, according to Rush, when asked how many seconds a man had lived who was 70 years, 17 days and 12 hours old, returned the correct answer in 90 seconds. When he died in 1790 at the age of 80, his obituary in the Columbian Centinel described his ability:

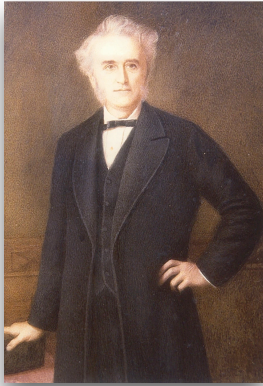
“He would give the number of poles, yards, feet, inches and barley-corns in a given distance—say, the diameter of the earth's orbit—and in every calculation he would produce the true answer in less time than ninety-nine out of a hundred men would take with their pens.”



Rush was not the first, however, to describe such a remarkable ability. Seven years before he wrote about Fuller, the case of Jedediah Buxton was described in a German journal. Buxton was unable to write and was described as having “limited knowledge,” but he could report the exact area in acres and square inches of the town of Elmton, England, where he grew up, simply by walking its perimeter. Assuming 48 hair-breadths to an inch, he could then give the area of the town in square hair-breadths. The same article noted that he was able to calculate the product of one farthing doubled 139 times (the result in pounds was a 39-digit



number). He was then able to multiply that number by itself, all in seconds and without benefit of paper and pencil.



John Langdon Down is known to us primarily for his description in 1862 of the syndrome that bears his name, which is now known to be caused by the presence of an extra copy of chromosome 21. In 1887 Down delivered a lecture to the Medical Society of London in which he described several cases of children with impressive numerical, artistic or musical skills but, in his description, “[whose] level of general ability was so poor that they were unable to live independently.” Down coined the term “idiot savant” to describe these individuals, and though the term “idiot” was, at the time, a medical term used to designate individuals with an IQ below 25, it had already taken on pejorative connotations and Down regretted its use. It also proved to be inaccurate, since many affected individuals have IQs above 25, some even in the normal range. Over time, this terminology has been discarded in favor of “savant syndrome.”

No precise, universally accepted definition of savant syndrome exists, but this one is as good as any and better than most. Dr. Darold Treffert was an expert at the University of Wisconsin until his death two years ago. Savant syndrome, he said, is “a condition in which persons with various developmental disabilities, including Autistic Disorder, have astonishing areas of brilliance, ability or talent—‘islands of genius’—that stand in jarring, marked contrast to overall handicap.”

Since striking examples of savantism are rare, most of us have become aware of the syndrome through the medium of television or, more recently, the internet. I’m going to take a few minutes to refresh our collective memory with some salient examples, beginning with Morley Safer’s 1983 interview of George Finn. Both George and his twin brother were calendrical savants who also possessed striking mnemonist, or memory abilities.

Although savant syndrome is not recognized as a mental disorder in the current Diagnostic and Statistical Manual (DSM-5), the diagnostic bible of the American Psychiatric Association, its defining salient characteristics are universally agreed upon, and are illustrated in the examples I have shown. It occurs in individuals with significant mental disabilities, whether congenital, developmental, or acquired later in life as a result of brain injury through trauma, infection or stroke, and is manifested by an isolated ability that would be considered unusual in a cognitively normal individual. Rarely, the ability far exceeds the abilities of even the most brilliant cognitively intact persons; these individuals are referred to as prodigious savants. At any given

time, there may be no more than 50 to 100 prodigious savants in the world population. Exceptional memory underpins all savant skills, though some are known precisely because of their prodigious, though specialized memory. Nine out of ten savants are male.

Another defining characteristic of savant syndrome is its close association with autism. About 50 percent of those with savant syndrome are autistic; the other fifty percent have other neurodevelopmental impairments. On the other hand, about one in ten persons with autism manifests some savant skill. Obviously, this close association must be taken into account by any theory that seeks to explain the phenomenon of savant syndrome.

I want to pause briefly here to talk about autism. Autism is so ubiquitous in the general population that you might surmise that it has been known for centuries, but it was first described in 1943 by Leo Kanner and independently the following year by Hans Asperger. It was not recognized as a new type of mental disorder by the DSM until 1980, and it was only in 2013 that the American Psychiatric Association revised the criteria, broadening the definition and introducing the concept of the spectrum, which ranges from the severely impaired who are unable to perform activities of daily living to those who are brilliant and achieve academic success.

Autism is considered a neurobiological, developmental condition that begins in early childhood and is characterized by (and here I am quoting from the DSM):

1. persistent deficits in social communication and social interactions across multiple contexts, including deficits in social-emotional reciprocity, deficits in nonverbal communicative behaviors used for social interaction, and deficits in developing, maintaining and understanding relationships,
2. restricted, repetitive patterns of behavior, interests or activities, such as stereotyped or repetitive motor movements such as lining up toys, use of idiosyncratic phrases or echolalia, insistence on sameness and inflexible adherence to routine, highly restricted, fixated interests that are abnormal in intensity or focus, and hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment,
3. symptoms are present in the early developmental period, usually by the age of 2 and
4. they cause clinically significant impairment of social or occupational functioning.
5. The DSM goes on to specify that autism may be accompanied by intellectual impairment or language impairment.

Not mentioned in the DSM definition is the fact that autism spectrum disorder is four times more common in boys.

Austrian pediatrician Hans Asperger, unaware of the recent description of autism by Leo Kanner, described a group of children who manifested “a lack of empathy, little ability to form friendships, one-sided conversations, intense absorption in a special interest, and clumsy movements,” and afflicted chiefly boys. Many of these children had no difficulty with language and had normal cognitive development, but had difficulty understanding irony, humor, sarcasm and facial gestures, especially when those facial expressions were not consonant with the underlying meaning of the verbal expression.

One might legitimately ask whether Kanner and Asperger were describing the same thing. The defining difference seems to be that persons with Asperger syndrome have normal cognitive and language development—as such, they might be considered a high-functioning form of autism. Indeed, Asperger syndrome was removed from the DSM in the most recent edition and is considered to be within the autism spectrum.

Before I discuss what is known about how savants do it, let’s take a few minutes to review what they do—the common types of savant skills. I referred earlier to Dr. Darold Treffert, who was on the faculty at the University of Wisconsin. Dr. Treffert ranked savant skills by their degree of complexity. **Splinter skills** are the most common. They involve an obsessive preoccupation with a narrowly focused field of interest. Dr. Treffert cited music and sports trivia, license plate numbers, maps, bus or train schedules, or historical facts. **Talented savants** express musical, artistic or other special abilities, usually within a single area of expertise, that are very conspicuous when viewed in contrast to the overall disability. **Prodigious savants** are those very rare individuals whose special skill is so outstanding that it would be spectacular even if it occurred in a non-impaired person.

Another way to consider savant skills is by the type of skill.

Calendrical skills are the most common. They typically emerge between the ages of 8 and 15. George Finn and his twin brother are outstanding examples.

Mathematical savants, like Thomas Fuller and Jedediah Buxton, previously noted, have strengths that are usually in one of two categories: hypercalculia or numerosity. Hypercalculia is the ability to perform mind-boggling mathematical calculations very rapidly. Joseph Sullivan, one of two savants who were models for the character Raymond Babbitt, portrayed by Dustin Hoffman in *Rain Man* (the other was Kim Peek), was asked, “What number times what number

gives 1,234,567,890?” It took him four seconds to give the answer: $137,174,210 \times 9$. Numerosity is a sort of numerical intuition that allows most people and some animals to estimate objects without actually counting them. Savants carry this ability to an incomprehensible extreme. Oliver Sacks, in his 1985 book, *The Man Who Mistook His Wife for a Hat*, described his first encounter with George and Charles Finn (you met George earlier; he was interviewed by Morley Safer) in a state mental hospital. A box of matches on the table fell, spilling its contents on the floor. Both twins exclaimed simultaneously, “111!” and they were correct. Sacks also claimed that the twins were able to generate 8, 10 and even 12-digit prime numbers, but his account has been challenged on several grounds.

Mnemonist savants are known specifically for their prodigious memory. As I said earlier, an exceptional memory is present in all savants, but most experts consider mnemonic skills to be a savant skill per se. Some are able to memorize entire books, although they might not understand the content. Some excel at maps, zip codes, sports statistics and other trivia, and their memory is usually not remarkable outside of their specific area of focus. Mnemonist savants must be distinguished from the even rarer hyperthymestic syndrome, which was first described in a California woman (~~AJ, now known to be Jill Price~~) in 2006. She has the ability to recall in vivid detail every day of her adult life— both significant and mundane events and events in the news. Her memory was described in the initial case study as “nonstop, uncontrollable, and automatic.” As of 2021, 61 cases have been identified worldwide.

Artistic savants possess extraordinary ability to draw, paint or sculpt, producing highly accurate images or sculptures, usually from memory. Stephen Wiltshire is a good example.

Musical savants like Kody Lee possess perfect pitch. Perfect pitch is present in about one in ten thousand in the general population, but one in twenty autistic individuals and possibly one in three savants. Sacks, in his book *Musicophilia*, describes the case of Martin, who developed meningitis at age three. He recovered, but with a residual seizure disorder, spastic weakness, an odd personality and limited intelligence. But he also was left with what Sacks dubbed a “phonographic memory” and a high order of musicianship. He was able to remember thousands of operas and other classical pieces and could reproduce a Debussy piece on the piano perfectly after hearing it once, then transpose it to another key and add Debussy-like improvisations. Stephen Wiltshire, the artist who can draw an entire metropolitan area after a brief helicopter flight, developed remarkable musical skills in his mid-teens. He has perfect pitch and can reproduce complex chords and melodies after a single hearing and transpose them to different keys.

Linguistic savants are extremely rare, which I will touch on later. It is not uncommon in some parts of the world for the majority of people to be multilingual. Many Europeans speak at least two languages. Educated people in Eritrea may speak three or four languages, and in New Guinea, where there are 871 languages and over 200 dialects, most educated people speak at least four. What sets linguistic savants apart from neurotypical multilinguals is that most have a low IQ and most have acquired their skills without formal education. Despite their linguistic abilities, most have difficulty communicating with others, particularly in non-verbal forms of communication. I don't know whether Vaughn Smith has savant syndrome but there are some clues in the Washington Post article. As a child he didn't understand his teachers. Other children laughed at him. To quote the Post article, "His parents and teachers often looked at him with disappointment...His teacher said he wasn't paying attention...it felt to Vaughn like there was something wrong with him." He met a Paraguayan special needs teacher while walking in a park. She took him home so he could hear Guaraní spoken (a surviving native language spoken by 90% of the Paraguayan population) and talked to him about the autistic children she taught. She described the traits of autism to him and he realized for the first time that autism might explain the difficulties he had understanding his teachers or why some adults considered him rude. The Washington Post article never says that Vaughn has been diagnosed as being autistic.

Another way to categorize savants is by whether the condition developed spontaneously or was acquired after some form of head trauma, brain infection, stroke or dementia. Treffert cited as an example an 8-year-old boy who underwent a left hemispherectomy to control a seizure disorder and thereafter developed calendar calculating abilities. He also reported the case of Daniel Tammet who, after developing a seizure disorder as a child, developed a remarkable ability to remember long strings of numbers. He was able to recite Pi to 22,514 places. I mentioned earlier the case of Martin, described by Oliver Sacks, who developed phenomenal musical skills after recovering from meningitis at age 3. One of the more recent and more public cases was that of Dr. Tony Cicoria, an orthopedic surgeon whose story has been reported by NPR, PBS, the New Yorker and many other outlets, and at length by Oliver Sacks in his book *Musicophilia*. Struck by lightning at age 42 while using a pay phone in 1994 (there were still pay phones in 1994), he would have died had there not been an ICU nurse waiting to use the phone. He developed memory problems and sluggishness. Those symptoms resolved over several weeks but were replaced by an insatiable desire to hear classical piano music. He bought recordings, acquired a piano, bought sheet music and began to teach himself. He also began to compose. Within months music consumed his life outside of the operating room. He began taking lessons

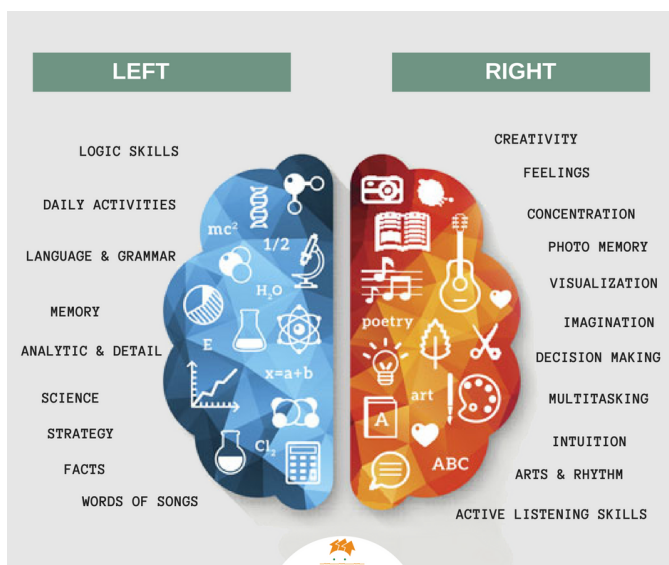
and developed his piano skills to the point that he was able to give concerts and play his own compositions—this in a man who had no real interest in music before his near-death experience.

More has been learned about savant syndrome in the past 30 years than in the 100 years before that. Still, research that seeks to explain the phenomenon of savantism faces several major hurdles. The first is that prodigious savants are extremely rare, and the prevalence of any form of savantism is low, so it is difficult to assemble cohorts of subjects to be studied. Another impediment is that there is not a precise definition of savantism, so direct comparison of studies lacks precision. For that matter, the breadth of the autism spectrum results in a lack of precision. The types of skills exhibited and the degree of those skills varies widely. And assessment tools are not standardized.

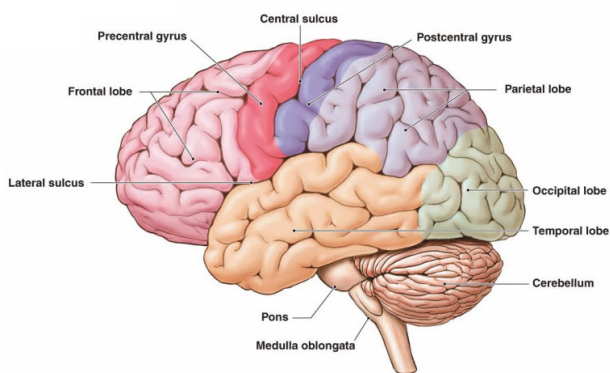
So what we have at this point are a number of theories. All of them have to account for the high prevalence of autism and the relatively high prevalence among males. No theory yet proposed explains everything we see, but some theories go a long way toward explaining the phenomenon and have wide acceptance. Most of the theories are highly technical and require a grounding in neuroanatomy and neural and psychological functioning. I don't profess expertise in these areas, but I would like to leave you with a broad though superficial understanding of how neuroscientists are thinking about the phenomenon of savantism. The theories basically fall into three categories (these are my categories): brain lateralization and damage, altered memory abilities, and a category I'll call "others."

Perhaps the major theory to help explain savant syndrome has to do with brain lateralization.

The idea that the right and left sides of the brain function differently grew out of work done in the 1960s. The early work revealed stark differences between the hemispheres: the left brain was more analytical and logical, did most of the heavy lifting in math and science and was more detail oriented. It was the verbal center, most responsible for speech and for reading and writing. The right brain was more intuitive, more creative, more imaginative. It dealt with spatial and visual tasks. It was more concrete. Where the left engaged in detail-oriented perception, the right was more holistic



in its approach, and was largely nonverbal. Over time, additional research has painted a more complex and nuanced picture. Both hemispheres are involved in most functions and work together. The brain is more plastic than we thought, able to rewire and relearn functions on one side when the other is damaged by trauma or stroke. Under normal circumstances, there is considerable interplay between the hemispheres, mediated physically through connecting neural pathways in a thick neural band that connects the hemispheres, the corpus callosum. One hemisphere may augment activity in the other. We know, too, that neural impulses may inhibit as well as excite other neural activity, a fact I will come back to in a moment. Some functions, like language, are largely, though not entirely, the domain of one hemisphere. Other functions are more equally shared, but this idea of hemisphere specialization retains validity. Out of this highly choreographed interplay of billions of excitatory and inhibitory neural pathways emerges consciousness, cognition, emotion, and personality.



© 2011 Pearson Education, Inc.

Research has shown that most—perhaps all—people with savant syndrome have damage of the left hemisphere, usually the left parietal and temporal lobes, and most savant skills are typical of right hemispheric functions. Linguistic savants are the exception and I will come back to that. The hypothesis is that left brain damage, whether due to intrauterine processes or later trauma, leads to right brain compensation. That is, areas of the right hemisphere rewire to assume

functions lost on the left. This is one of the possible connections to autism. It was noted in the mid-1970s that in autism, there is a relationship between left brain dysfunction and assumption of left brain functions by the right.

There is direct empiric evidence that supports this left brain damage hypothesis. Most cases of acquired savantism arise after damage to the left hemisphere. I have mentioned some cases, and there are others, like a boy reported in 1980 who developed savant mechanical skills after a gunshot wound of the left hemisphere. And then there are the intriguing observations made in some people who develop frontotemporal dementia. (Frontotemporal dementia is a degenerative process in the frontal or temporal lobes and is characterized by behavioral and personality changes. It is one of the more common causes of early onset dementia.) Some of these patients exhibit a striking emergence of artistic or musical skills that tend to persist even as the dementia progresses. This disease often develops first in the left hemisphere, resulting in a loss of

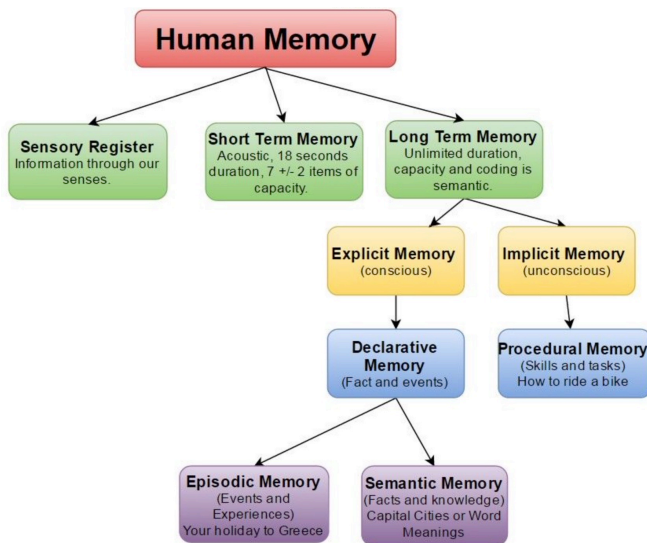
symbolic thought but heightened visual creativity that lacks symbolic content and abstract elements. Interestingly, but not surprising, frontotemporal dementia patients may exhibit autistic-like behaviors—particularly obsessive, intensive focus on their artwork. They may paint the same subject multiple times.

In recent years, researchers have developed a way to test the left hemisphere damage hypothesis by creating temporary interruptions of left hemisphere function using repetitive transcranial magnetic stimulation. TMS is an FDA-approved treatment for depression and has been used to treat autism and schizophrenia. Sessions last about 40 minutes and do not require anesthesia or sedation. The magnetic field created can be focused to induce an electrical field that can interrupt target area activities. In 2006 TMS was used experimentally to interrupt normal activity of the left anterior temporal lobe (the area most commonly damaged in savants) in 12 normal subjects. Researchers found that ten improved their ability to guess numbers of discreet items presented in a picture. Since then, a meta-analysis of 60 studies along the same lines showed that TMS results in transiently improved speed and accuracy on tasks involving attention, memory and language. This obviously cannot be explained by so-called rewiring—the growth of new neurons and new connections between neurons—but it might well be explained by temporary interference with left brain inhibition of right brain function.

A related theory that helps to explain not only the dominance of right brain characteristics but also the male predominance in both autism and savant syndrome has to do with *in utero* development of the brain. It has been known for some time that the left hemisphere develops more slowly than the right. This more rapid development of the right hemisphere is thought to allow for perceptual functions to be present very soon after birth, which would offer survival advantages. The left brain develops more slowly, continuing to develop conceptual and linguistic powers after birth. As it does so, it begins to inhibit some of the perceptual powers of the right hemisphere. This allows us to see the world more globally, to integrate disparate pieces of information into a unified whole to which we react. If the left brain were not inhibiting the perceptual powers of the right, we would be bogged down by minutia, unable to see the forest because we are constantly focusing on the trees. So we know that the left brain develops a bit more slowly than the right. It has also been shown that testosterone further slows the development of the left hemisphere. The hypothesis proposes that excessive testosterone levels during a critical juncture might slow left hemisphere development a bit too much and result in the migration of dominance to the right hemisphere. This can be thought of as a prenatal form of left hemisphere damage that would not necessarily be detectable by imaging technologies, but would result in functional abnormalities.

As I alluded to when talking about TMS, it has been suggested that left hemisphere injury, rather than resulting in a compensatory rewiring in the right hemisphere, so that the right hemisphere takes over what were previously left hemisphere functions, instead results in a decrease in left hemisphere inhibition of right hemisphere functions, what one researcher called “the benevolent tyranny of the left hemisphere.” So rather than compensating by developing new capacity, dormant capacity that already exists in the right hemisphere is allowed to emerge. This suggests that to some degree these extraordinary capacities exist in all of us, but are inhibited by the benevolent tyranny of the left hemisphere.

Earlier I touched on the phenomenal but specialized memory that undergirds all savant abilities. We tend to think of memory as a single, monolithic ability, but that is not the case. The special type of memory that characterizes savants has been described as automatic, mechanical, and concrete. It allows for the remembering of facts without comprehension of their meaning, what one researcher termed “memory without reckoning.” Dr. Darold Treffert has called it “unconscious memory.” What we normally think of when we talk about memory involves cognition—“memory with reckoning”.



Here’s a diagram of the types of memory. What we’re talking about in savant syndrome is an abnormality that occurs earlier in the information acquisition and storage process. Neurologists talk about three basic steps. Sensory memory is the raw input data coming from our five senses. It is extremely ephemeral, lasting a fraction of a second to no more than a few seconds. It is an image held in the mind’s eye when we turn away from something. Short term memory lasts for a matter of seconds unless some conscious or unconscious mechanism moves it to long

term memory. Psychologists sometimes use the term eidetic memory to refer to sensory memory. The abnormal memory possessed by savants occurs somewhere between sensory memory and short term memory. Some savants have the ability to hold stable, detailed images in their mind’s eye much longer—a sort of abnormally prolonged eidetic or sensory memory. Why this happens is not known. While we think of this as a phenomenal ability, it may actually arise

due to an impaired ability to forget. There is a protective or adaptive benefit to being able to discard images no longer needed.

One savant skill that does not fit well into the left brain injury theory is the very rare polyglot savant. Polyglots are defined as those who speak six or more languages, hyperpolyglots speak eleven or more. More than half of earth's population speak more than one language, but what defines a savant polyglot is that most have a low IQ, lack formal instruction, and their language ability contrasts sharply with their handicap in other domains. One of the best studied is Christopher, first described in 1995, who is able to speak, write and translate sixteen languages—possibly more, but Christopher has severe difficulties in non-verbal cognitive domains. I said that polyglot savants do not fit neatly into the left brain injury theory because language is an almost exclusively left brain function. Most savants develop skills that largely pertain to the uninjured right hemisphere. Christopher has evidence of left hemisphere damage, yet has a highly developed ability attributed to that hemisphere. This contradiction has not been explained by existing theories. Vaughn Smith, with whom I began this talk, underwent functional MRI scanning at MIT. The Washington Post article does not describe any evidence of left hemisphere damage, but, curiously, the scan showed less than normal oxygen uptake in those centers of the brain that process language—evidence that his brain does not work as hard as would be expected in producing speech. This has been observed in other polyglots who have been studied.



Another related theory is called “weak central coherence.” This theory is based on the observation that autistic individuals have a cognitive style that focuses on details. They see and think about details but have great difficulty seeing the larger picture. They perform well on tasks that may benefit from not being able to see the larger picture. This cognitive style might result, in some individuals, in a sustained, very tight focus of interest that allows the emergence of an isolated skill.

The hypersystemising hypothesis builds on the Weak Central Coherence theory. It says that a hyperfocus on detail is not sufficient for the emergence of savant skills, that savants seek to discern underlying patterns, that they develop law-based pattern recognition to impose an order on the detail. We all engage in systemizing to understand and organize the world around us, but this hypersystemisation takes the process to an extreme that could explain why skills such as determining prime numbers or calendar calculation might emerge.

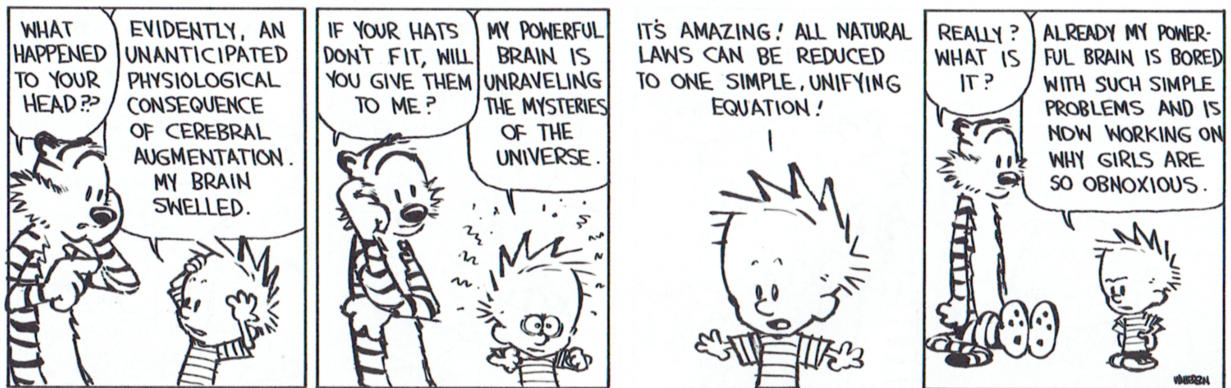
There are other hypotheses. Some are based, like the weak central coherence theory, on abnormal types of cognition. Some are based, as I have discussed, on abnormal types of memory function. There are genetic theories, based on the observation that many with autism and savant syndrome share an abnormality on a short arm of the 15th chromosome that might give rise to a particular type of cognitive impairment. Treffert has hypothesized that prodigious savants have knowledge of and access to the vast rules and syntax of music, or art or mathematics that they have not acquired by exposure or formal training; that they have this access through another form of memory he calls “ancestral memory”—basically, the genetic transmission of knowledge. This is controversial since there is no direct evidence of a genetic transmission of knowledge. It is true, though, that persons with autism are more likely to have a father or grandfather who was an engineer.

These hypotheses and others contribute to our understanding of how savant syndrome might emerge, but none fully explains the wide spectrum of observed skills. These hypotheses are not mutually exclusive. In fact, the best combine to help explain what we observe: the high correlation with autism, the frequent presence of damage to the left parietal and temporal lobes, the male predominance and other factors.

Any discussion of these theories must recognize a key point made by Dr. Darold Treffert: these skills do not just happen; they are developed over time, abetted by a very narrowly focused, intense and unrelenting interest and a remarkable, even phenomenal, though narrowly focused

memory. The skills are improved by practice and are rewarded by attention and appreciation from others.

My reading on this subject has caused me to reflect on what a remarkable organ the human brain is. Even as it works to explain the origins of the cosmos, of life itself, our evolution, and our relationship to this fragile planet that is our home, it also struggles to understand itself. The rare islands of genius we observe offer us tantalizing clues to capabilities locked away within each of us, and provide avenues for future research that promise not only insights and treatments for autism and other cognitive disorders, but might also reveal opportunities to expand human cognitive potential. Someday in the future we might have the ability, such as that created by Calvin's Atomic Cerebral Enhance-O-Tron, to enhance our ability to solve some of the deepest mysteries of the universe.



References

Oswaldo Cairó Battistutti, The Savant Syndrome: Intellectual Impairment, Astonishing Condition, Amazon Books, 2021.

Diagnostic and Statistical Manual of Mental Disorders, 5th Ed., American Psychiatric Association, 2013.

Treffert DA, The savant syndrome in autistic disorder: recent developments in autism research, Nova Science Publishers, Inc., 2005.

Zeldovich L, The evolution of ‘autism’ as a diagnosis explained, Spectrum News website (<https://www.spectrumnews.org/news/evolution-autism-diagnosis-explained/>)

Chan E, Etiology and expression of savant syndrome: insight into the inner working of the human brain, University of British Columbia’s Undergraduate Journal of Psychology (vol 2), 2013.

Contrera J, The remarkable brain of a carpet cleaner who speaks 24 languages, Washington Post, 5 Apr 2022.

Eidetic memory, Wikipedia, accessed October 2022.

Sacks O, Musicophilia: tales of music and the brain, Vintage Books, New York, 2007.

Charuchandra S, Savant in the limelight, 1988–2009, The Scientist Magazine, 2020.

Hughes JA et al., Savant syndrome has a distinct psychological profile in autism, Molecular Autism, 2018.

Jeon Y, Savant syndrome: a review of research findings, Culminating projects in special education, 2016 (https://repository.stcloudstate.edu/sped_etds/25)

Schipperhelin JAM and FJ Dunne, The savant syndrome: genius and mental handicap combined, Psychiatric Bulletin 14: 475-476, 1990.

Darius H and Katie Valli, Savant syndrome - theories and empirical findings, Digitala Vetenskapliga Arkivet (DiVA), 2007.

Agarwala Y, Understanding savant syndrome: the accidental genius, Imperial Bioscience Review (online), 2021.