MOZART, FEDERER, PICASSO, BECKHAM, AND THE SCIENCE OF SUCCESS

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Mozart, Federer, Picasso, Beckham, and the Science of Success

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The Talent Myth

The Hidden Logic of Success

The Autobiographical Bias

In January 1995, I became the British number-one table tennis player for the very first time, which, I am sure you will agree, is a heck of an achievement. At twenty-four years of age, I suddenly found myself on the receiving end of regular invitations to speak to school audiences about my rise to international glory, and would often take my gold medals along to dazzle the youngsters.

Table tennis is a pretty big sport in the UK, with 2.4 million participants, 30,000 paid-up members of the governing body, thousands of teams, and serious riches for those who excel. But what made me special? What had marked me out for sporting greatness? I came up with a number of attributes: speed, guile, gutsiness, mental strength, adaptability, agility, reflexes.

Sometimes I would marvel at the fact that I had these skills in such abundance that they were capable of elevating me—little me!—beyond hundreds of thousands of others aspiring for that precious top spot. And all this was doubly amazing, considering I had been born into a family in an ordinary suburb of an ordinary town in southeast England. There was no silver spoon. No advantages. No nepotism. Mine was a triumph of individuality; a personal odyssey of success; a triumph against the odds.

This, of course, is the way that many who have reached the top in sport, or indeed in any other field, choose to tell their stories. We live in a culture that encourages this kind of soaring individualism. Hollywood is full of such narratives, often sugarcoated in American Dream sentimentality. But while these stories are inspirational, rousing, and compulsively entertaining, are they true? Here is my story in table tennis, retold with the bits that I chose to ignore the first time around, as they diminished the romance and the individuality of my triumph.

1. Table

In 1978 my parents, for a reason they are still unable to explain (neither of them play table tennis), decided to buy a table tennis table—a super deluxe 1000 with gold lettering, since you ask—and to put it in our large garage. I do not know the exact percentage, but you can imagine that there were not many youngsters of my age in my hometown who possessed a full-size, tournament-specification table. Fewer still had a garage in which it could be housed full-time. This was my first bit of good fortune.

2. My Brother

My second piece of good fortune was having an older brother named Andrew who came to love table tennis as much as I. We would play for hours in the garage after school: dueling, battling, testing each other's reflexes, experimenting with new spins, investigating new paddles, inviting friends over, who

although often more accomplished in other sports, were bemused to see just how far we had advanced in table tennis. Without knowing it, we were blissfully accumulating thousands of hours of practice.

3. Peter Charters

Mr. Charters was a teacher at the local primary school, a tall man with mustache, a twinkle in his eye a disdain for conventional teaching methods, and a passion for sports that bordered on the fanatical. He was the coach of almost all of the after-school sporting clubs, the manager of the school soccer team, the organizer of school sports day, custodian of the badminton equipment, and inventor of a game called “Bucket Ball,” a kind of improvised basketball.

But Charters cared about one thing above all: table tennis. He was the nation’s top coach and a senior figure in the English Table Tennis Association. The other sports were just a front; an opportunity to scout sporting talent wherever it emerged so he could focus it—ruthlessly and exclusively—upon table tennis. No child who passed through Aldryngton School in Reading was not given a tryout by Charters. And such was his zeal, energy, and dedication to table tennis that anybody who showed potential was persuaded to take their skills forward at the local club, Omega.

Charters invited me and my brother Andy to join Omega in 1980, at the very moment we were beginning to outgrow the garage.

4. Omega

Omega was not a luxurious club—it was a one-table hut in a gravel enclosure a couple of miles from where we lived in suburban Reading: cold in winter, ferociously hot in summer, with plants growing through the roof and floor. But it had one advantage that made it almost unique anywhere in the county: it was open twenty-four hours a day, for the exclusive use of its tiny group of members, each of whom had a set of keys.

My brother and I took full advantage, training after school, before school, on weekends, and during the holidays. We were also joined by other Aldryngton alumni who had been spotted and snapped up by Charters, so that by 1981 Omega was becoming something of a sensation. One street alone (Silverdale Road, on which the school was situated) contained an astonishing number of the nation’s top players.

At number 119 were the Syeds. Andrew, my brother, went on to become one of the most successful junior players in the history of the UK, winning three national titles before retiring due to injury in 1986. He was later described by Charters as the best young player to emerge from England for a quarter of a century. Matthew (that’s me) also lived at 119 and became a long-serving England senior number one, a three-time Commonwealth champion, and a two-time Olympian.

At number 274, just opposite Aldryngton, lived Karen Witt. She was one of the most brilliant female players of her generation. She won countless junior titles, the national senior title, the hugely prestigious Commonwealth championship, and dozens of other competitions in a sparkling career. When she retired with back trouble at the age of twenty-five, she had changed the face of women’s table tennis in England.

At number 149, equidistant between the Syeds and the Witts, lived Andy Wellman. He was a powerful player who would go on to win a series of titles, mainly in doubles, and was widely feared, particularly after defeating one of the top English players in the prestigious Top 12 event.

At the bottom of Silverdale Road was Paul Trott, another leading junior, and Keith Hodder, an

outstanding county player. Around the corner were Jimmy Stokes (England junior champion), Paul Savins (junior international), Alison Gordon (four times English senior champion), Paul Andrews (to national player), and Sue Collier (England schools champion). I could go on.

For a period in the 1980s, this one street, and the surrounding vicinity, produced more outstanding table tennis players than the rest of the nation combined. One road among tens of thousands of roads; one tiny cohort of schoolkids against millions up and down the country. Silverdale Road was the wellspring of English table tennis: a Ping-Pong mecca that seemed to defy explanation or belief.

Had some genetic mutation spread throughout the local vicinity without touching the surrounding roads or villages? Of course not: the success of Silverdale Road was about the coming together of factors of a beguilingly similar kind to those that have, from time to time, elevated other tiny areas o our planet into the sporting ascendancy (Spartak, an impoverished tennis club in Moscow, for example, created more top-twenty women players between 2005 and 2007 than the whole of the United States).

In particular, all of the sporting talent was focused ruthlessly on table tennis, and all of the aspirin players were nurtured by an outstanding coach. And as for me, with a table in the garage and a brothe as passionate about Ping-Pong as myself, I had a head start before I even got to Aldryngton.

The Myth of Meritocracy

My parents—bless them—continue to describe my success in table tennis as an inspirational triumph against the odds. That is kind indeed, and I thank them for it. When I showed them a draft of this chapter, they disputed its entire thesis. Yes, but what about Michael O'Driscoll (a rival from Yorkshire)? He had all your advantages, but he didn't make it. What about Bradley Billington (anoth rival from Derbyshire)? He had parents who were international table tennis players, but he did not become England's number one.

This is merely a slightly different twist on what I call the autobiographical bias. My point is not th I was a bad table tennis player; rather, it is that I had powerful advantages not available to hundreds o thousands of youngsters. I was, in effect, the best of a very small bunch. Or, to put it another way, I was the best of a very big bunch, only a tiny fraction of whom had my opportunities.

What is certain is that if a big enough group of youngsters had been given a table at eight, had a brilliant older brother to practice with, had been trained by one of the top coaches in the country, had joined the only twenty-four-hour club in the county, and had practiced for thousands of hours by thei early teens, I would not have been number one in England. I might not have even been number one thousand and one in England. Any other conclusion is a crime against statistics (it is of course *possible* that I would have been number one, but the possibility is strictly theoretical).

We like to think that sport is a meritocracy—where achievement is driven by ability and hard work —but it is nothing of the sort. Think of the thousands of potential table tennis champions not fortuna enough to live on Silverdale Road, with its peculiar set of advantages. Think of the thousands of potential Wimbledon champions who have never been fortunate enough to own a tennis racket or receive specialized coaching. Think of the millions of potential major-winning golfers who have nev had access to a golf club.

Practically every man or woman who triumphs against the odds is, on closer inspection, a beneficiary of unusual circumstances. The delusion lies in focusing on the individuality of their triumph without perceiving—or bothering to look for—the powerful opportunities stacked in their

favor.

This is one of the central points made by Malcolm Gladwell in his marvelous book *Outliers*. Gladwell shows how the success of Bill Gates, the Beatles, and other outstanding performers is not so much to do with "what they are like" but rather "where they come from." "The people who stand before kings may look like they did it all by themselves," Gladwell writes. "But in fact they are invariably the beneficiaries of hidden advantages and extraordinary opportunities and cultural legacies that allow them to learn and work hard and make sense of the world in ways others cannot."

Whenever I am inclined to think I am unique and special, I remind myself that had I lived one door farther down the road, I would have been in a different school district, which would have meant that I would not have attended Aldryngton, would never have met Peter Charters, and would never have joined Omega. It is often said that in elite sport the margins of victory and defeat are measured in milliseconds: the reality is that they are measured in variables that are far more elusive.

But it is worth pausing here for a moment to consider an objection. You may agree with the thrust of the argument that opportunity is *necessary* for success, but is it *sufficient*? What about the natural gifts that mark out the very best from the rest? Are these skills not necessary to get to a Wimbledon final or the top of an Olympic podium? Are they not vital to becoming a chess grandmaster or the CEO of a multinational? Is it not delusional to suppose that you (or your children) can achieve great success without also possessing rare talent?

This has been the abiding presumption of modern society ever since Francis Galton, an English Victorian polymath, published his book *Hereditary Genius*. In the book, Galton wields the insights of his half cousin Charles Darwin to come up with a theory of human achievement that remains in the ascendancy to this day.

"I propose to show," Galton wrote, "that a man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical features of the whole organic world…. I have no patience with the hypothesis…that babies are born pretty much alike and the sole agencies in creating differences…are steady application and moral effort."

The idea that natural talent determines success and failure is, today, so powerful that it is accepted without demur. It *seems* indisputable. When we watch Roger Federer caressing a cross-court forehand winner or a chess grandmaster playing twenty games simultaneously while blindfolded or Tiger Woods launching a 350-yard fade, we are irresistibly drawn to the conclusion that they possess special gifts not shared by the rest of us.

The skills are so qualitatively different, so detached from our own lives and experience, that the very idea that we could achieve similar results if given the same opportunities seems nothing less than ridiculous.

The metaphors we use to describe outstanding achievers encourage this way of thinking. Roger Federer, for example, has been said to have "tennis encoded in his DNA." Tiger Woods is said to have been "born to play golf." Top performers subscribe to this way of thinking, too. Diego Maradona once claimed he was born with "soccer skill in my feet."

But is talent what we think it is?

What Is Talent?

In 1991 Anders Ericsson, a psychologist at Florida State University, and two colleagues conducted the most extensive investigation ever undertaken into the causes of outstanding performance.

Their subjects—violinists at the renowned Music Academy of West Berlin in Germany—were divided into three groups. The first group comprised the outstanding students: the boys and girls expected to become international soloists, the pinnacle of musical performance. These were the kids who would normally be described as supertalented, the youngsters supposedly lucky enough to have been born with special musical genes.

The second group of students was extremely good, but not as accomplished as the top performers. These students were expected to end up playing in the world's top orchestras, but not as star soloists. In the final group were the least able students: teenagers studying to become music teachers, a course with far less stringent admission standards.

The ability levels of the three groups were based on the assessment of the professors and corroborated by objective measures such as success in open competitions.

After a painstaking set of interviews, Ericsson found that the biographical histories of the three groups were remarkably similar and showed no systematic differences. The age when the students began practice was around eight years old, which was the same time when they began formal lessons. The average age when they first decided to become musicians was just before they turned fifteen. Th average number of music teachers who had taught them was 4.1, and the average number of musical instruments that they had studied beyond the violin was 1.8.

But there was one difference between the groups that was both dramatic and unexpected; indeed, it was so stark that it almost jumped out at Ericsson and his colleagues—the number of hours devoted t serious practice.

By the age of twenty, the best violinists had practiced an average of ten thousand hours, *more than two thousand hours more than the good violinists* and *more than six thousand hours more than the violinists hoping to become music teachers*. These differences are not just statistically significant; they are extraordinary. Top performers had devoted thousands of additional hours to the task of becoming master performers.

But that's not all. Ericsson also found that there were no exceptions to this pattern: nobody who ha reached the elite group without copious practice, and nobody who had worked their socks off but failed to excel. Purposeful practice was the only factor distinguishing the best from the rest.

Ericsson and his colleagues were astounded by these findings, sensing that they heralded a paradigm shift in the way excellence is understood—that it is practice, not talent, that ultimately matters. "We deny that these differences [in skill level] are immutable; that is, due to innate talent," they wrote. "Instead we argue that the differences between expert performers and normal adults refle a life-long persistence of deliberate effort to improve performance."

The aim of the first part of this book is to convince you that Ericsson is right; that talent is not wha you think it is; that you can accomplish all manner of things that seem so far beyond your current capabilities as to occupy a different universe. But this will not be a wishy-washy exercise in the powe of positive thinking. Rather, the arguments will be grounded in recent findings in cognitive neuroscience that attest to the way the body and mind can be transformed with specialized practice.

After all, what *is* talent? Many people feel sure they know it when they see it; that they can look at group of kids and discern from the way they move, the way they interact, the way they adapt, which o them contain the hidden genes necessary for success. As the managing director of a prestigious violin school puts it: "Talent is something a top violin coach can spot in young musicians that marks them out as destined for greatness."

But how does the teacher know that this accomplished young performer, who looks so gifted, has not had many hours of special training behind the scenes? How does she know that the initial differences in ability between this youngster and the rest will persist over many years of practice? In fact, she doesn't, as a number of studies have demonstrated.

An investigation of British musicians, for example, found that the top performers had learned no faster than those who reached lower levels of attainment: hour for hour, the various groups had improved at almost identical rates. The difference was simply that top performers had practiced *for more hours*. Further research has shown that when top performers seem to possess an early gift for music it is often because they have been given extra tuition at home by their parents.

But what about child prodigies—kids who reach world class while still in adolescence? Have they not learned at a super-fast rate? Well, no. As we shall see in the next chapter, child prodigies may loo as if they have reached the top in double-quick time, but the reality is that they have compressed astronomical quantities of practice into the short period between birth and adolescence.

As John Sloboda, professor of psychology at Keele University, puts it: "There is absolutely no evidence of a 'fast track' for high achievers." Jack Nicklaus, the most successful golfer of all time, has made the same point: "Nobody—but *nobody*—has ever become really proficient at golf without practice, without doing a lot of thinking and then hitting a lot of shots. It isn't so much a lack of talent; it's a lack of being able to repeat good shots consistently that frustrates most players. And the only answer to that is practice."

The same conclusion—about the primacy of practice—is arrived at by widening the perspective, a Ericsson has shown. Just consider the way in which standards have risen dramatically in just about every area of human endeavor. Take music: When Franz Liszt composed "Feux Follets" in 1826, it was said to be virtually unplayable; today it is performed by every top pianist.

The same is true in sports. When the winner of the men's 100 meters in the 1900 Olympics clocke 11.0 seconds, it was considered a miracle; today that time would not be sufficient to qualify for the final of the high school national trials. In diving, the double somersault was almost prohibited in the 1924 Olympics because it was considered dangerous; now it is routine. The fastest time for the marathon in the 1896 Olympics was just a few minutes faster than the entry time for the Boston Marathon, which is met by thousands of amateurs.

In academia, too, standards are spiraling ever upward. Thirteenth-century English scholar Roger Bacon argued that it was impossible to master mathematics in less than thirty to forty years; today calculus is taught to almost every college student. And so it goes on.

But the key point is that these improvements have not occurred because people are getting more talented: Darwinian evolution operates over a much longer time span. They must have occurred, therefore, because people are practicing longer, harder (due to professionalism), and smarter. It is the quality and quantity of practice, not genes, that is driving progress. And if that is true of society, why not accept that it is also true of individuals?

So the question is: How long do you need to practice in order to achieve excellence? Extensive research, it turns out, has come up with a very specific answer to that question: from art to science an from board games to tennis, it has been found that a minimum of ten years is required to reach world class status in any complex task.

In chess, for example, Herbert Simon and William Chase, two American psychologists, found that nobody had attained the level of an international grandmaster "with less than a decade's intense preparation with the game." In music composition, John Hayes also found that ten years of dedicatio is required to achieve excellence, a verdict that features centrally in his book *The Complete Problem Solver*.

An analysis of the top nine golfers of the twentieth century showed that they won their first international competition at around twenty-five years of age, which was, on average, more than ten years after they started golfing. The same finding has been discovered in fields as diverse as mathematics, tennis, swimming, and long-distance running.

The same is even true in academia. In a study of the 120 most important scientists and 123 most

famous poets and authors of the nineteenth century, it was found that ten years elapsed between their first work and their best work. Ten years, then, is the magic number for the attainment of excellence.

In *Outliers*, Malcolm Gladwell points out that most top performers practice for around one thousand hours per year (it is difficult to sustain the quality of practice if you go beyond this), so he redescribes the ten-year rule as the ten-thousand-hour rule. This is the minimum time necessary for the acquisition of expertise in any complex task. It is also, of course, the number of hours that the top violinists had practiced in the Ericsson experiment.*

Now think about how often you have heard people dismiss their own potential with statements like "I am not a natural linguist" or "I don't have the brain for numbers" or "I lack the coordination for sports." Where is the evidence for such pessimism? Often it is based upon nothing more than a few weeks or a few months of halfhearted effort. What the science is telling us is that *many thousands of hours of practice* are necessary to break into the realm of excellence.

Before going on, it's worth emphasizing something about the upcoming chapters: the truth of the arguments will have urgent implications for the way we choose to live our lives. If we believe that attaining excellence hinges on talent, we are likely to give up if we show insufficient early promise. And this will be perfectly rational, given the premise.

If, on the other hand, we believe that talent is not (or is only marginally) implicated in our future achievements, we are likely to persevere. Moreover, we will be inclined to move heaven and earth to get the right opportunities for ourselves and our families: the right teacher, access to decent facilities the entire coalition of factors that leads to the top. And, if we are right, we *will eventually excel*. Wha we decide about the nature of talent, then, could scarcely be more important.

To conclude this section, here's an example from *Outliers* that evokes the twin insights of modern research on excellence: namely, the importance of *opportunity* on the one hand and *practice* on the other.

In the mid-1980s, Roger Barnsley, a Canadian psychologist, was with his family at a Lethbridge Broncos ice hockey game when he was alerted by his wife—who was leafing through the program—t what looked like an extraordinary coincidence: many of the players had birthdays in the early months of the calendar.

"I thought she was crazy," Barnsley told Gladwell. "But I looked through it, and what she was saying just jumped out at me. For some reason, there were an incredible number of January, February and March birth dates."

What was going on? Had a genetic mutation affected only those Canadian hockey players born in the early part of the year? Was it something to do with the alignment of the stars in the early part of the calendar?

In fact the explanation was simple: the eligibility cutoff date for all age-based hockey in Canada is January 1. That means that a ten-year-old boy born in January could be playing alongside another boy born almost twelve months later. This difference in age can represent a huge difference in terms of physical development at that time of life.

As Gladwell puts it:

> This being Canada, the most hockey-crazed country on earth, coaches start to select players for the traveling "rep" squad—the all-star teams—at the age of nine or ten, and of course they are more likely to view as talented the bigger and more coordinated players, who have had the benefit of critical extra months of maturity.
>
> And what happens when a player gets chosen for a rep squad? He gets better coaching, and his teammates are better, and he plays fifty or seventy-five games a season instead of twenty games a season…. [By] the age of thirteen or fourteen, with the benefit of better coaching and all that extra

practice under his belt, he really *is* better, so he's the one more likely to make it to the Major Junio A league, and from there into the big leagues.

The skewed distribution of birth dates is not limited to the Canadian junior hockey league. It is als seen in European youth soccer and U.S. youth baseball; indeed, most sports where age-based selectio and streaming are part of the process of molding the stars of the future.

This punctures many of the myths that cling to elite performers. It shows that those who make it to the top, at least in certain sports, are not necessarily more talented or dedicated than those left behind it may just be that they are a little older. An arbitrary difference in birth date sets in train a cascade o consequences that, within a matter of a few years, has created an unbridgeable chasm between those who, in the beginning, were equally well equipped for sporting stardom.

Month of birth is, of course, just one of the many hidden forces shaping patterns of success and failure in this world. But what most of these forces have in common—at least when it comes to attaining excellence—is the extent to which they confer (or deny) opportunities for serious practice. Once the opportunity for practice is in place, the prospects of high achievement take off. And if practice is denied or diminished, no amount of talent is going to get you there.

This speaks directly to my experiences in table tennis. With a table tennis table in the garage at home and a brother to practice with, I had a head start on my classmates. It was only a slight head start, but it was sufficient to create a *trajectory of development* with powerful long-term consequences. My superior ability was taken for evidence of talent (rather than lots of hidden practice), and I was selected for the school team, leading to yet more practice sessions. Then I joined Omega, the local club, then the regional team, then the national team.

By the time—a few years later—I was given a chance to perform in an exhibition match in front o the whole school, I possessed skills of an entirely different kind from those of my classmates. They stomped their feet and cheered as I whipped the ball back from all parts of the court. They marveled my finesse and coordination and the other "natural gifts" that marked me out as an outstanding sportsman. But these skills were not genetic; they were, in large part, *circumstantial*.

In the same vein, it is not difficult to imagine a spectator in the stands of a major league hockey match watching in awe as a former classmate scores a winning goal of spellbinding brilliance. You can imagine him standing and applauding and, later, congregating with friends for an after-match drink to eulogize his hero and to reminisce about how he once played hockey alongside him at schoo

But now suppose you suggested to the hockey fan that his hero—a player whose talent seems so irrepressible—might now be working in the local hardware store had his birthday been a few days earlier; that the star player could have strained every sinew to reach the top, but his ambition would have been swept away by forces too powerful to resist and too elusive to alter.

And now imagine suggesting to the fan that it is just possible that he may himself have become an all-star ice hockey player had his mother given birth just a few hours later: on January 1 instead of December 31.

He would probably think you were crazy.

Talent Is Overrated

If I were to utter random consonants one after the other with, say, a one-second pause between each one, how many do you think you could you repeat back to me? Let's try the experiment with the

letters on the next page. Read along the line, pausing for a second or two at each letter; then, when yo
get to the end, close the book and see how many you can recall.

JELCGXORTNKLS

I'm guessing you managed around six or seven. If so, you are proving the basic tenet of one of the most renowned papers in cognitive psychology: "The Magical Number Seven, Plus or Minus Two," b George A. Miller of Princeton University, published in 1956. In that paper, Miller showed that the memory span of most adults extends to around seven items, and that greater recall requires intense concentration and sustained repetition.

Now consider the following feat of memory achieved by a person known in the literature as "SF" i a psychology lab at Carnegie Mellon University in Pittsburgh on July 11, 1978. The experiment was conducted by William Chase, a leading psychologist, and Anders Ericsson (the man who would later undertake the study of the violinists in Berlin).

They were testing SF on the digit span task. In this test, a researcher reads a list of random numbe one per second, before asking the subject to repeat back as many digits, in order, as she can remembe On this day SF is being asked to recall an amazing twenty-two digits. Here is how SF got on, as described by Geoff Colvin in his wonderful book *Talent Is Overrated*:

> "All right, all right, all right," he muttered after Ericsson read him the list. "All right! All right. Oh…geez!" He clapped his hands loudly three times, then grew quiet and seemed to focus further. "Okay. Okay…. Four-thirteen-point-one!" he yelled. He was breathing heavily. "*Seventy-seven eighty-four!"* He was nearly screaming. *"Oh six oh three!"* Now he was screaming. *"Four-nine-four, eight-seven-oh!"* Pause. *"Nine-forty-six!"* Screeching now. Only one digit left. But it isn't there. *"Nine-forty-six-point…Oh, nine-forty-six-point…"*
>
> He was screaming and sounding desperate. Finally, hoarse and strangled: *"TWO!"* He had done it. As Ericsson and Chase checked the results, there came a knock on the door. It was the campus police. They'd had a report of someone screaming in the lab area.

Pretty amazing and rather dramatic, is it not? But this memory performance by SF was just the beginning. A little time later SF managed forty numbers, then fifty. Eventually, after 230 hours of training over a period of almost two years, SF managed to recall eighty-two digits, a feat that, if we were to watch it unfold before our eyes, would lead us to the conclusion that it was the product of special "memory genes," "superhuman powers," or some other phrase from the vocabulary of expert performance.

This is what Ericsson calls the iceberg illusion. When we witness extraordinary feats of memory (o of sporting or artistic prowess), we are witnessing the *end product of a process measured in years*. What is invisible to us—the submerged evidence, as it were—is the countless hours of practice that have gone into the making of the virtuoso performance: the relentless drills, the mastery of technique and form, the solitary concentration that have, literally, altered the anatomical and neurological structures of the master performer. What we do not see is what we might call the hidden logic of success.

This is the ten-thousand-hour rule revisited, except that now we are going to dig down into its meaning, its scientific provenance, and its application in real lives.

SF was selected by the researchers with one criterion in mind: his memory was no better than average. When he embarked on his training, he was able to remember only six or seven digits, just lik you and me. So the amazing feats he eventually achieved must have been due not to innate talent, but to practice. Later, a friend of SF's reached 102 digits, with no indication that he had reached his

ceiling. As Ericsson puts it, “There are apparently no limits to improvements in memory skill with practice.”

Think about that for a moment or two, for it is a revolutionary statement. Its subversive element is not its specific claim about memory but its promise that *anybody* can achieve the same results with opportunity and dedication. Ericsson has spent the last thirty years uncovering the same groundbreaking logic in fields as diverse as sports, chess, music, education, and business.

“What we see again and again is the remarkable potential of ‘ordinary’ adults and their amazing capacity for change with practice,” says Ericsson. This is tantamount to a revolution in our understanding of expert performance. The tragedy is that most of us are still living with flawed assumptions: in particular, we are laboring under the illusion that expertise is reserved for special people with special talents, inaccessible to the rest of us.

So, how did SF do it? Let’s look again at the letter-remembering exercise. We saw that, under normal circumstances, remembering more than six or seven letters is pretty difficult without a great deal of concentration and without constantly repeating the letters to oneself. Now try remembering th thirteen letters on the next page. I suspect you will be able to do so without any difficulty whatsoever indeed, without even bothering to read through the letters one by one.

ABNORMALITIES

Piece of cake, wasn’t it? Why? For the simple reason that the letters were arranged in a sequence, pattern, that was instantly familiar. You were able to recall the entire series of letters by, as it were, encoding them in a higher-order construct (i.e., a word). This is what psychologists call “chunking.”

Now, suppose I was to write down a list of random words. We know from our previous exercise tha you would probably be able to remember six or seven of them. That is the number of items that can b comfortably stored in short-term memory. But, at thirteen letters per word, you would, by implicatio be remembering around eighty letters. By a process of “chunking,” you have been able to remember a many letters as SF remembered numbers.

Think back to SF’s battle with the digit span task. He kept saying things like “Three-forty-nine-point-two.” Why? Geoff Colvin explains: “[W]hen he heard the digits 9 4 6 2, he thought of it as 9 minutes, 46.2 seconds, an excellent time for running two miles. Similarly, 4 1 3 1 became 4:13.1, a mile time.”

SF’s “words” were, in effect, mnemonics based on his experience as a club runner. This is what psychologists call a retrieval structure.

Now, let’s take a detour into the world of chess. You’ll be aware that chess grandmasters have astonishing powers of recall and are able to play a mind-boggling number of games at the same time, without even looking at the boards. Alexander Alekhine, a Russian grandmaster, once played twenty-eight games simultaneously while blindfolded in Paris in 1925, winning twenty-two, drawing three, and losing three.

Surely these feats speak of psychological powers that extend beyond the wit of “ordinary” people like you and me. Or do they?

In 1973, William Chase and Herbert Simon, two American psychologists, constructed a devastatingly simple experiment to find out (Chase is the researcher who would later conduct the experiment with SF). They took two groups of people—one consisting of chess masters, the other composed of novices—and showed them chessboards with twenty to twenty-five pieces set up as they would be in normal games. The subjects were shown the boards briefly and then asked to recall the positions of the pieces.

Just as expected, the chess masters were able to recall the position of every piece on the board,

while the nonplayers were able to place only four or five pieces. But the genius of the experiment wa about to be revealed. In the next set of tests, the procedure was repeated, except this time the pieces were set up not as in real games, but randomly. The novices, once again, were unable to recall more than five or so pieces. But the astonishing thing is that the experts, who had spent years playing chess *were no better*: they were also stumped when trying to place more than five or six pieces. Once again what looked like special powers of memory were in fact nothing of the kind.

What was going on? In a nutshell, when chess masters look at the positions of the pieces on a boar they see the equivalent of a word. Their long experience of playing chess enables them to chunk the pattern with a limited number of visual fixations in the same way that our familiarity with language enables us to chunk the letters constituting a familiar word. It is a skill derived from years of familiarity with the relevant "language," not from talent. As soon as the language of chess is disrupte by the random positioning of pieces, chess masters find themselves looking at a jumble of letters, jus like the rest of us.

The same findings extend to other games like bridge, and much else besides. Time and again, the amazing abilities of experts turn out to be not innate gifts but skills drawn from years of dedication that disappear as soon as they are transported beyond their specific realm of expertise. Take SF. Even after he had built up the capacity to remember an astonishing eighty-two numbers, he was unable to recall more than six or seven random consonants.

Now let's shift up a gear by taking these insights into the realm of sports.

The Mind's Eye

In December 2004 I played a game of tennis with Michael Stich, the former Wimbledon tennis champion from Germany, at the Harbour Club, a plush sports facility in west London. The match was part of a promotional day pitting journalists against top tennis players to publicize an upcoming competition at the Royal Albert Hall in London. Most of the matches were lighthearted affairs, with Stich hamming it up and giving the journalists the runaround, much to the amusement of onlookers. But when I came up against Stich, I wanted to conduct a little experiment.

I asked Stich to serve at maximum pace. He has one of the fastest serves in the history of the sport —his personal best is 134 mph—and I was curious to see whether my reactions, forged over twenty years of international table tennis, would enable me to return it. Stich smiled at the request, graciously assented to it, and then spent a good ten minutes warming up, loosening his shoulders and torso to gain maximum leverage on the ball. The onlookers—around thirty or so club members—suddenly became very curious, and the atmosphere a little tense.

Stich came back onto court sporting a light sweat, bounced the ball, and glanced across the net, as was his routine. I crouched down and focused hard, coiled like a spring. I was confident I would retur the serve, although I was not certain it would be much more than a soft mid-court lob. Stich tossed th ball high into the air, arched his back, and then, in what seemed like a whirl of hyperactivity, launche into his service action. Even as I witnessed the ball connecting with his racquet, it whirred past my right ear with a speed that produced what seemed like a clap of wind. I had barely rotated my neck by the time it thudded against the soft green curtains behind me.

I stood up straight, bemused, much to Stich's merriment and that of the onlookers, many of whom were squealing with laughter. I couldn't fathom how the ball had traveled so effortlessly fast from hi racquet onto the court, and then pinged past my head. I asked him to send down another, then another

He served four straight aces before approaching the net with a shrug of the shoulder and a slap of my back. He told me that he had slowed down the last two serves to give me a fighting chance. I hadn't even noticed.

Most people would conclude from this rather humbling experience that the ability to connect with, let alone return, a serve delivered at more than 130 mph must belong exclusively to those with innate reaction speeds—what are sometimes called instincts—at the outer limits of human capability. It is a inference that almost jumps up and bites you when the ball has just rocketed so fast past your nose that you're relieved at having avoided injury.

But I was forbidden from reaching any such conclusion. Why? Because in different circumstances, *have those extraordinary reaction speeds*. When I stand behind a table tennis table, I am able to react to, and return, smash-kills in the blink of an eye. The time available to return a serve in tennis is approximately 450 milliseconds; but there are fewer than 250 milliseconds in which to return a smash-kill in table tennis. So, why could I return the latter and not the former?

In 1984 Desmond Douglas, the greatest ever UK table tennis player, was placed in front of a screen containing a series of touch-sensitive pads at the University of Brighton. He was told that the pads would light up in a random sequence and that his task was to touch the relevant pad with the index finger of his favored hand as soon as he could, before waiting for the next pad to light up. Douglas wa highly motivated, as all the other members of the team had already undergone the test and were ribbing him in the familiar manner of team rivalry.

First one pad, then another, lit up. Each time Douglas jabbed his finger toward the pad, his eyes scanning the screen for the next target. After a minute, the task ended and Douglas's teammates (I wa one of them: at thirteen years of age, I was at my first senior training camp) gave him a round of applause. Douglas grinned as the researcher left the room to collate the results. After five minutes, th researcher returned. He announced that Douglas's reactions were the slowest in the entire England team: he was slower than the juniors and the cadets; slower even than the team manager.

I remember the intake of breath to this day. This wasn't supposed to happen. Douglas was universally considered to have the fastest reactions in world table tennis, a reputation he continues to command more than ten years after his retirement. His style was based on standing with his stomach couple of inches from the edge of the table, allowing the ball to ricochet from his paddle using lightning reflexes that astounded audiences around the world. He was so sharp that even the leading Chinese players—who had a reputation for extreme speed—were forced to retreat when they came up against him. But here was a scientist telling us that he had the most sluggish reactions in the whole of the England team.

It is not surprising that, after the initial shock, the researcher was laughed out of the room. He was told that the machine must be faulty or that he was measuring the wrong data. Later, the England team manager informed the science staff at Brighton that their services would no longer be required. Sport science was a new discipline back then, and the England manager had shown unusual innovation in seeing if his team could benefit from its insights, but this experiment seemed to prove that it had littl to teach table tennis.

What nobody considered—not even the unfortunate researcher—was that Douglas really *did* have the slowest reactions in the team, and that his speed on a table tennis court was the consequence of something entirely different. But what?

I am standing in a room at Liverpool John Moores University in the northwest of England. In front of me is a screen containing a life-size projection of a tennis player standing at the other end of a virtual court. An eye-tracking system is trained on my eyes, and my feet are placed on sensors. The whole thing has been put together by Mark Williams, professor of motor behavior at Liverpool John Moores and arguably the world's leading expert on perceptual expertise in sport.

Mark hits the play button and I watch as my "opponent" tosses the ball to serve and arches his back. I am concentrating hard and watching intently, but I have already demonstrated why I was unable to return the serve of Stich.

"You were looking in the wrong place," says Mark. "Top tennis players look at the trunk and hips of their opponents on return in order to pick up the visual clues governing where they are going to serve. If I was to stop the picture in advance of the ball being hit, they would still have a pretty good idea about where it was going to go. You were looking variously at his racquet and the arm, which give very little information about the future path of the ball. You could have had the fastest reactions in history, and you still would not have made contact with the ball."

I ask Mark to replay the tape and adjust my focus to look at the places rich in information, but it makes me even more sluggish. Mark laughs. "It is not as simple as just knowing about where to look; it is also about grasping the meaning of what you are looking at. It is about looking at the subtle patterns of movement and postural clues and extracting information. Top tennis players make a small number of visual fixations and 'chunk' the key information."

Think back to the master chess players. You'll remember that when they looked at a board, they saw words: that is to say, they were able to chunk the position of the pieces as a consequence of their long experience of trying to find the best moves in chess games. Now we can see that the very same thing is happening in tennis.

When Roger Federer returns a service, he is not demonstrating sharper reactions than you and I; what he is showing is that he can extract more information from the service action of his opponent and other visual clues, enabling him to move into position earlier and more efficiently than the rest of us, which in turn allows him to make the return—in his case a forehand cross-court winner rather than a queen to checkmate.

This revolutionary analysis extends across the sporting domain, from badminton to baseball and from fencing to football. Top performers are not born with sharper instincts (in the same way that chess masters do not possess superior memories); instead, they possess enhanced awareness and anticipation. In cricket, for example, a first-class batsman has already figured out whether to play off the back foot or front foot more than 100 milliseconds before a bowler has even released the ball.

As Janet Starkes, professor emerita of kinesiology at McMaster University, has put it, "The exploitation of advance information results in the time paradox where skilled performers seem to have all the time in the world. Recognition of familiar scenarios and the chunking of perceptual information into meaningful wholes and patterns speeds up processes."

The key thing to note is that these cannot possibly be innate skills: Federer did not come into this mortal world with knowledge of where to look or how to efficiently extract information on a service return any more than SF was born with special memory skills (he wasn't: that is precisely why he was selected by Ericsson) or chess players have innate board-game memory skills (remember that their advantage is eliminated when the pieces are randomly placed).

No, Federer's advantage has been gathered from experience: more precisely, it has been gained from a painstaking process of encoding the meaning of subtle patterns of movement drawn from more than ten thousand hours of practice and competition. He is able to see the patterns in his opponent's movements in the same way that chess players are able to discern the patterns in the arrangement of pieces on a chessboard. It is his regular practice that has given him this expertise, not his genes.