How to become the world record holder for solving the Rubik's cube

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Dear Sebastiano, first of all thank you for agreeing to this interview. Let's start from the beginning of it all, when you solved a Rubik's cube for the first time. How did you figure it out? Did you find it easy as you make it seem now?

No, not at all! In fact I did not even figure it out on my own. I was I think around 10 years old and there was this cube lying around in my house. My mother taught me how to solve it, but she could not remember one of the steps for the last layer. So my method at the time was based on trial-and-error: solve the first two layers and check if the "missing step" happened to be solved by chance, and if so finish it; otherwise, start over from the first layer on another side... Now I know that the "missing step" happens to be solved 1 out of 12 times.
A few years later I had internet access and youtube existed, so I decided to look up how to improve my technique. I found out that with some practice I could drastically improve my solving time, and that there were many people around the world doing it as a hobby. So speedcubing became my hobby too, and I have not stopped since then.

How much time do you dedicate to this hobby? Do you train every day?

Almost every day, yes! When I was in high school and I had plenty of free time I would practice one or two hours a day, but now it's more like 20-30 minutes, maybe more in the weekends.

Most people would be satisfied with solving the cube once. What makes it interesting for you to scramble and solve it over and over again?

Every configuration of the cube has something unique, and with $8! \cdot 12! \cdot 3^7 \cdot 2^{10}$ combinations you would never get the same one twice. Even though the most basic methods are repetitive and frankly a bit boring, there is a great variety of advanced techniques that require some more reasoning.
But maybe the main reason why I like this as a hobby is that it gives me a quantitative way to measure my improvement: when the cube is solved I look at the timer and the time is lower than what I used to get a few months or years ago. Challenging other people is also fun, but the competition against myself has always been more important for me.

Maybe in general you can tell us how you became a world champion, like the difficulties that you encountered on this path?

Soon after picking up this hobby I started practicing for many different challenges that are officially sanctioned by the World Cube Association (WCA). One of them I found particularly intriguing is blindfolded solving, meaning that one first memorizes the configuration of the cube and solves it without looking at it.

At my first official competition, in 2011, I was already pretty good and I was aiming at the national record for the 3x3x3 blindfolded event. Unfortunately I felt the pressure and I could not complete any of the three attempts I was given - a common problem for first-time blindfolded competitors. Despite this I had acceptable results in the other events and I enjoyed my first competition a lot.

One year later I attended a competition that hosted the fewest moves challenge. In this event the competitor is given a sequence of moves to reach a certain randomly-generated cube state (the scramble), and they have one hour to find the shortest solution possible for that configuration. Of course, submitting the inverse of the scramble is not allowed.

After some practice I found myself naturally good at this, perhaps because I had already a good grasp on the cube and I knew multiple techniques to solve it. With a bit of luck, I was able to clutch my first national record in this event, with a result of 28 moves - my personal best at the time!

Between 2012 and 2017 I improved many national records, in different events: the aforementioned fewest moves, one-handed solving, 4x4x4 and 5x5x5 blindfolded and the elusive 3x3x3 blindfolded.

In 2017 I also attended the World Championship in Paris, my first large international competition. I was prepared to do well in the blindfolded event, and I was not disappointed at all with my 6th place, but I even managed to place 2nd in the fewest moves challenge! Later that year I also missed the European record for 3x3x3 blindfolded by 0.01 seconds, but I redeemed myself by becoming European champion for that event in 2018.

In January 2019 I got my first world record: a 24 moves average for 3 attempts in the fewest moves challenge. For official records, both the average of the given attempts and the single results are recorded: if an average is available then that is used to determine the winner, but smaller competitions may not be able to afford 3 attempts for long events such as fewest moves solving.

My record did not last long and was beaten multiple times in the following months, but I got it back in June, this time setting both a new best single result (16) and average of 3 attempts (22).

Less than a month after setting the new records I took part in the World Championship in Melbourne, and I knew I had a good shot at winning the fewest moves challenge. On the first of the three attempts I got a 25, which was ok. On the second one I got a 24, while most of my rivals struggled. At that point I was ahead of everyone else by at least two moves, I knew I only needed a "good enough" result on the third attempt to win. But unfortunately I got an underwhelming 28 and I placed third.

In early 2020, before the pandemic broke out, I have also lost my 22 moves average world record to an amazing 21 average by Cale Schoon (USA), although I still hold the best single result undisputed.

Maybe some people would like to know this: Do you consider solving the Rubik's cube to be a mathematical exercise?

Doing a one-hour fewest moves attempt is reminiscent of solving a math problem: one needs to try many different things and find out the best approach for that specific configuration, and a lot of creativity is needed.

For fast solves, not so much. Some of the techniques that speedcubers use are based on some mathematical concepts: for example commutators, a technique to swap around 3 pieces of your choice without affecting any other piece, are, well, commutators as in group theory. As a mathematician I understand these concepts, but it is not necessary to know the math behind them in order to apply them.

Can you maybe explain, at least in part, your tricks or your main strategy to solve the Rubik's cube? More precisely, how do you solve blindfolded a 5x5x5 cube?

My strategy is no secret: there are many different ways to solve the cube and one can learn them from many sources online. It just takes some work to master the more complex ones.

I use different methods depending on the challenge. For the classic 3x3x3 speedsolve I use a method called Roux, which consists of solving two opposite "rectangular" blocks, then the remaining 4 corners and finally the last 6 edges.

For solving the cube blindfolded the more common methods are not great, because when you focus on solving a specific group of pieces you move the others all around the cube. But for blindfolded solving you need to move only a few pieces at the time and leave the others fixed where you saw them at the beginning. In practice I encode the cube configuration by remembering the permutation cycles of the pieces, and I solve them by splitting these cycles as a product of 3-cycles with a common buffer piece, plus some special cases for 2-cycles and other tricks. This technique works for cubes of any number of layers.

And for the fewest moves challenge, do you have any special trick? In other words do you know if the other participants to the competition were doing kind of the same?

This challenge is particular in that one can use many situational tricks to exploit each configuration in a different way. As I said before, I have no secret: I have even written a 70-page tutorial, available for free online, to explain all my techniques.

Remarkably, in both my world record in January and June 2019 I have used what was at the time a very niche method. This method was mostly obscure, and I myself had used it only a couple of times before. Nonetheless a few other competitors used it, with good results, but nobody came close to my 16 moves solution.

This method, which is basically an adapted version of the 4-step Thistlethwaite's algorithm, gained a lot of popularity and by the end of the year it became the standard. I have no doubt that if a similar lucky configuration pops up at a future large competition many people would be able to find the same solution!

Now let us come back to the normal people. Well, not only the normal people, because in fact many established mathematicians never went beyond solving the first layer of the Rubik's cube. How would you teach the Rubik's Cube to children so that they are not discouraged?

I think the hardest part of teaching it to a child would be keeping their interest alive and avoiding them getting discouraged. It would be important to choose a suitable duration for the lessons and maybe alternate the teaching part with a demonstrative part: showing how to make patterns, how one can move it fast…

Solving the 2x2x2 Rubik's cube is possibly more difficult than solving the first layer of the standard Rubik's Cube, am I correct?

Indeed it is! The reason is that the other pieces of the 3x3x3 can be used as "blank slots" to move your layer pieces around, giving you more freedom of movement.

Do you think that some gender or ethnic minorities are underrepresented, as usual for the wrong reasons, while playing with the Rubik's cubes?

As often happens in these more "nerdy" hobbies, women are underrepresented. I don't know the reasons for this, but I think they are not different from the reasons why women are underrepresented in chess or in mathematics. The cubing community is generally very welcoming towards everyone, including gender and ethnic minorities, but if one is scared to take the first step and join the community they will never find out.

It is worth mentioning that there is no separate ranking or competition for women, nor there are age categories, and I strongly agree with this policy. It would not feel right for me to win a 3x3x3 blindfolded event if Berta Garcia Parra, who has been a long time rival of mine but is now definitely faster than me, competes in her own category! Not to mention other female speedcubers like Juliette Sébastien, who is one of the fastest in Europe if not in the whole World, or Yiwei Liu, who is now ahead of me in the world ranking for the fewest moves challenge with an average of 21.67 (that makes her second in the world). I think giving more publicity to these talented speedcubers can motivate more girls to take up this hobby.

Which are normally the strongest countries in the world?

In general, rich and large countries such as the USA, China, Australia, Canada and most of western Europe. Poland is a remarkable exception, rivarlying China and the USA in terms of performance.

What do you think that one can do to attract potential talents to this kind of sport or hobby?

Personally I think that it is not hard to attract curious young people to this hobby: there are lots of resources online to learn and many videos of the champions showing off their skills.

Do you think that being good, say, at playing chess helps or the other way round, namely are you good at playing chess or other games?

I do not think that being good at one thing implies being good at another, but there can be some similarity. The reason is that if someone is good at chess it means that they practiced a lot and with the right mentality. And this is all it takes to become a good speedcuber: contrary to what many might think, it is not so much a matter of natural skills as of hard work and training.

Which kind of mathematics related to the Rubik's cube would you choose to explain in outreach activities and how?

There are many things that can be done, depending on the level of the audience.
For elementary/middle school students one can explain very basic combinatorics using only the color/sticker description of the cube. For example, once I explained an audience of 11-12 year old how to count how many vertices and how many edges a cube has by double counting: each of the 6 sides of the cube has 4 vertices, but each corner piece of the cube contains 3 colored stickers, which means that you are counting each one 3 times; so a cube has 6*4/3 = 8 vertices.
For high school students or a general non-mathematical audience, one can explain more complex combinatorics facts, such as counting the number of permutations of the corners (allowing to take apart the cube piece by piece).
For an undergraduate mathematics audience some group theoretic aspects can be explained. In this context the cube is a very nice concrete example of a group, and this can be very useful for example when studying permutation groups: for me the well-known fact that the cycle structure of a permutation is invariant under conjugation has alway been clear *in practice*, thanks to the cube.
Also, proving which configurations can be reached by only turning the cube's sides (i.e. without disassembling it) and which are "unsolvable" is a nice side project for an algebra student.
Finally, the more computational-inclined audience might find it interesting to learn the different techniques used to program a software that can solve the cube.

Now suppose that some young person is able to solve the cube. Would you recommend this person to enter the world of competitive cube solving? In fact, how can this be done in practice?

Yes, absolutely! In fact the kind of competitiveness that one encounters in this environment is very positive. Most rivals are also friends, and free exchange of ideas and helping each other out is much more present than the desire of winning. Moreover, nobody really cares if you are fast or slow: everyone goes at their own pace and tries mainly to improve themselves.
In practice, just go to the website of the World Cube Association [see https://www.worldcubeassociation.org/], find a competition near you and follow the instructions to sign up for it. You won't regret it! Unfortunately now in 2021 there are not many competitions available and the few spots available fill up quickly, so you might need to set a reminder for the day the registrations open!

Can you explain what was the role of Google in computing the minimal amount of moves for a cube?

Yes, I can make a summary. Since the cube came out in the 80s, many mathematicians tried to find lower and upper bounds for the minimum number of moves required to solve any random configuration, the so-called God's number. In 2010 the current lower bound for this number was 20, and a team consisting of Tomas Rokicki, Herbert Kociemba, Morley Davidson and John Dethridge developed a program to prove that this was indeed the correct number. However, even after an incredible work of optimization, this would have still required about 35 years to run on a normal PC. So Google kindly donated some of their computational power to run the program, and indeed it was found that the God's number is 20. [See http://cube20.org/.]
Do you think that AI can learn to solve the cube better than you do?
Yes, it already can! There is a recent paper on Nature about it [See https://www.nature.com/articles/s42256-019-0070-z.] It is also worth noticing that using classical techniques, such as tree-search and pruning tables, a computer can easily find a very short solution in the blink of an eye, and a good program can find an optimal solution in a matter of seconds or minutes for the hardest ones.

That was my last question, so thank you for your time and also for having shared your strategy. And great success with your future career. I also wish you to keep having fun with the cube for the rest of your life.

See also the following video of THE RUBIK SHOW
moderated by Nicole Paschek (Science Communicator at the University of Luxembourg)