or,

Rubik's Cubes Probably Seem Tough To Solve, But They're Actually Not That Hard, But People Are Still Really Good At Them
This Talk

2 ideas:

1. Rubik's cubes *aren't that hard* to solve
2. ...but people are still *really good* at them
A Brief History of Rubik's Cubes
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It
Really, It Isn't

"43 quintillion combinations!"
Really, It Isn't
Rubik's Cubes for Beginners

Think **pieces**, not **stickers**

- **corner** (3 colors)
- **edge** (2 colors)
- **center** (1 color)
"Algorithms"

Just a sequence of moves

- **Right, Up, Front, Left, Down, Back**
- R (clockwise), R2 (180 degrees), R' (counter-clockwise)

**Fast!**

- F (R U' R' U') (R U R' F') (R U R' U') (R' F R F')
Rubik's Cubes for Beginners

ruwix.com/the-rubiks-cube/how-to-solve-the-rubiks-cube-beginners-method/
Step 1: White Cross

Easy: just try for a while
Step 2: White Corners

**Pretty easy:** a couple of tricks to help

- **Example:** R' D' R
Step 3: Middle Layer

**Algorithm**: insert one edge

- \((U \ R \ U' \ R') \ (U' \ F' \ U \ F)\)
Step 4: Orient Edges

**Algorithm**: flip two edges

- $F \ (R \ U \ R' \ U') \ F'$
Step 5: Permute Edges

Algorithm: swap two edges

- R U R' U R U2 R' U
Step 6: Permute Corners

**Algorithm**: cycle three corners

- (U R U' L') (U R' U' L)
Step 7: Orient Corners

**Algorithm:** spin corners until cube is solved

- R' D' R D to solve one corner, then U for next corner
That's It!

7 steps and 5 algorithms; just takes practice

- White cross & corners: intuitive
- Middle layer: \((U \ R \ U' \ R') \ (U' \ F' \ U \ F)\)
- Orient edges: \(F \ (R \ U \ R' \ U') \ F'\)
- Permute edges: \((R \ U \ R' \ U) \ (R \ U^2 \ R' \ U)\)
- Permute corners: \((U \ R \ U' \ L') \ (U \ R' \ U' \ L)\)
- Orient corners: \(R' \ D' \ R \ D\)
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It
Faster Methods

Beginner method: 60 seconds

Better: the Fridrich method (aka: CFOP)

- Cross
- F2L ("first two layers")
- OLL ("orient last layer")
- PLL ("permute last layer")

Jessica Fridrich: CFOP can get 13 seconds
Step 2: F2L

F2L: **combine** white corners and middle layer

- ~41 different cases
- Still uses **intuition**

\[(U' \ R \ U' \ R) \ (U' \ R \ U2 \ R')\]
Step 3: OLL

OLL: orient yellow corners and edges at the same time

- "2 look OLL": 9 algorithms
- Full OLL: 57 algorithms
Step 4: PLL

PLL: permute yellow corners and edges at the same time

- Full PLL: 21 algorithms

\[ \begin{align*}
G_4: & \quad [R \ U \ R'] \ y' \ R2 \ u' \ R \ U' \ R' \ U' \ R' \ u \\
& \quad R2 \\
F: & \quad [R' \ U2 \ R' \ d'] \ [R' \ F'] \ [R2 \ U' \ R' \ U] \\
& \quad [R' \ F \ R \ U' \ F] \\
Z: & \quad M2 \ U \ M2 \ U \ M' \ U2 \ M2 \ U2 \ M' \ U2 \\
Y: & \quad F \ R \ U' \ R' \ U' \ [R \ U \ R' \ F'] \ ([R \ U \ R' \ U'] \ [R' \ F \ R \ F'])
\end{align*} \]
More?

ZBLL: with edges oriented, solve the last layer in **1 step**

- **493 algorithms**
- Impossible to recognize which one to use
- Why do people do this to themselves
Speedcubing
Speedcubing

Regulation solves:

- Judges apply random scramble
- 15 seconds inspection time
- +2 for 1 turn away; DNF for more

Records for single solve or Bo5
People Are Really Good At It
People Are Really Good At It
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It
Beyond 3x3

Other Rubik's cubes
Beyond 3x3

Other Rubik's cubes
Beyond 3x3

Other Rubik's cubes
More Pieces = More Difficulty?

Not much harder than 3x3, and 4x4 is biggest difficulty jump

Solution:

1. Build **centers**
2. Build **edges**
3. Pretend it's a 3x3
Step 1: Build the Centers

Pretty easy to do intuitively
Step 2: Build the Edges

Takes a bit more thought, but no algorithms
Step 3: Pretend it's a 3x3
Step 3.5: Except When It's Not A 3x3

(edge *parity*)
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It
People Are Really Good At It

Records for other sizes:

- 2x2: 0.49
- 4x4: 17.42
- 5x5: 36.06
- 6x6: 1:13.82
- 7x7: 1:40.89
...most of the time
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It Blindfolded
This one can't be serious, right?

How can you *remember all of the stickers*?

How do you *keep track of them* when you turn the cube?

This must take a *photographic memory*, right?
The BLD Secret

Use **PLLs** to make **small changes**

\[(F (R U' R' U') (R U R F') (R U R' U') (R' F R F'))\]
How to Memorize a Rubik's Cube

Only need to remember a chain of pieces

- Piece 1 belongs in spot 2…
- ...which belongs in spot 3…
- ...
- ...which belongs in spot 1!

To solve:

- Swap 1 and 2
- Swap 1 and 3
- ...
- Done!

Corners and edges are separate!
How to Memorize a Rubik's Cube

Remember the **chain** with a **memory palace**

- **Label each piece** with a letter
- Turn chain into a **sequence of letters**
- Imagine objects in your house, office, commute, …
- **Crazy = memorable!**
How to Memorize a Rubik's Cube

How much memory does it take?

- Usually 6-8 corners, 10-12 edges
- Total: 16-20 letters
- Like remembering **two phone numbers** for a few minutes
- **Executing accurately** is the harder part
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It Blindfolded
BLD Cubing

Different rules for blind solves

- No inspection
- Timing includes memorization
People Are Really Good At It

Blindfolded WR: 15.50 s

- < 7 second memorization!
People Are Really Good At It

Big cubes
People Are Really Good At It
Solving Rubik's Cubes Isn't That Hard, But People Are Really Good At It.
Other Twisty Puzzles
Other Twisty Puzzles

Make cool shapes!
Other Twisty Puzzles
"But Rubik's Cubes Are Mathematical!"

Rubik's cubes are related to **group theory**

- Rubik's cube group: permutations of the pieces
- Interesting fact: only **1/12 of arrangements are possible**
Solving Rubik's Cubes

Speedsolving is about **practice**, not **genius**

- Algorithms come from **computers**
- **Muscle memory** from (hundreds of) thousands of solves

...but the results are still mind-blowing
Twisty Puzzles

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