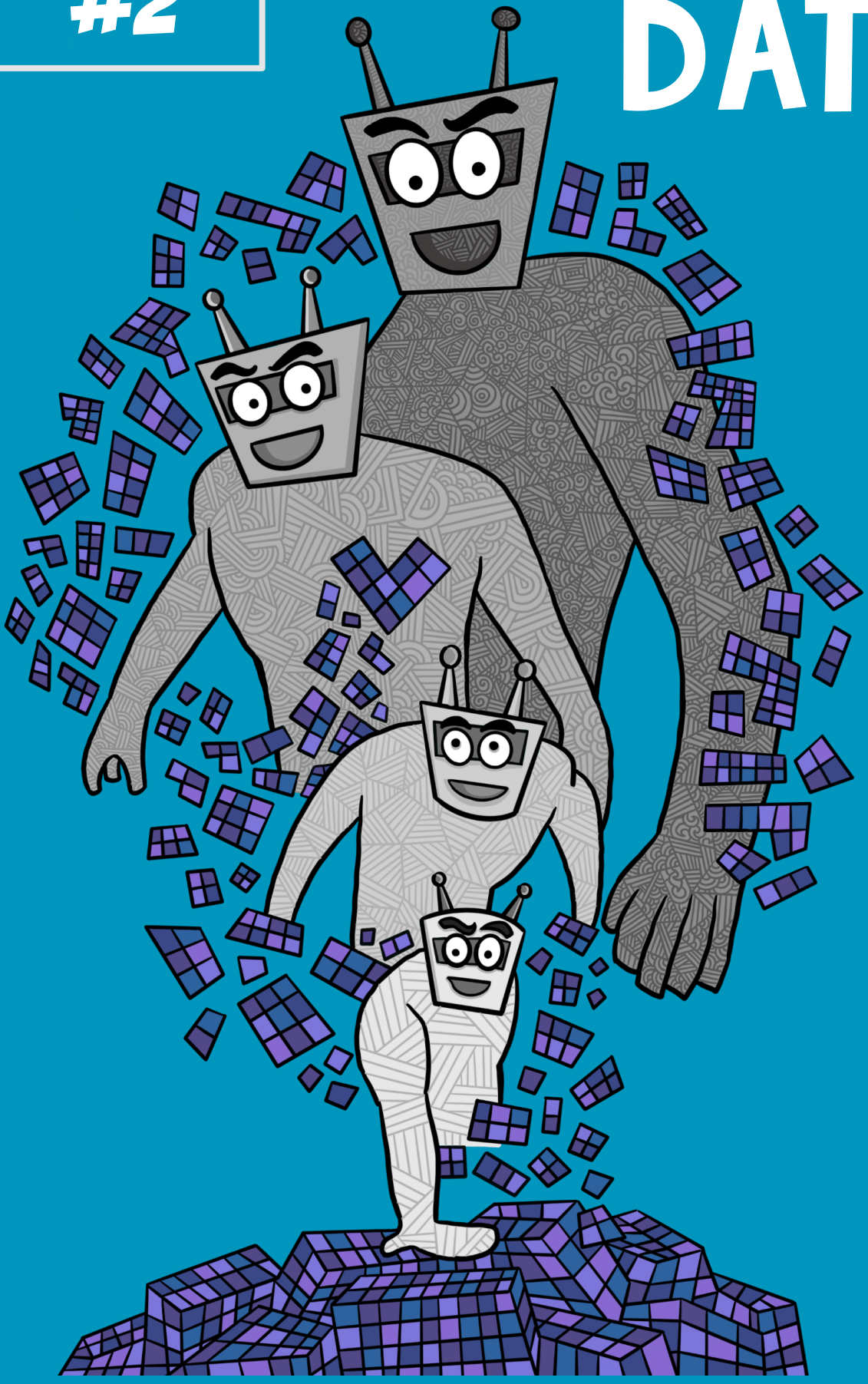
WE ARE AI
#2

Learning From DATA



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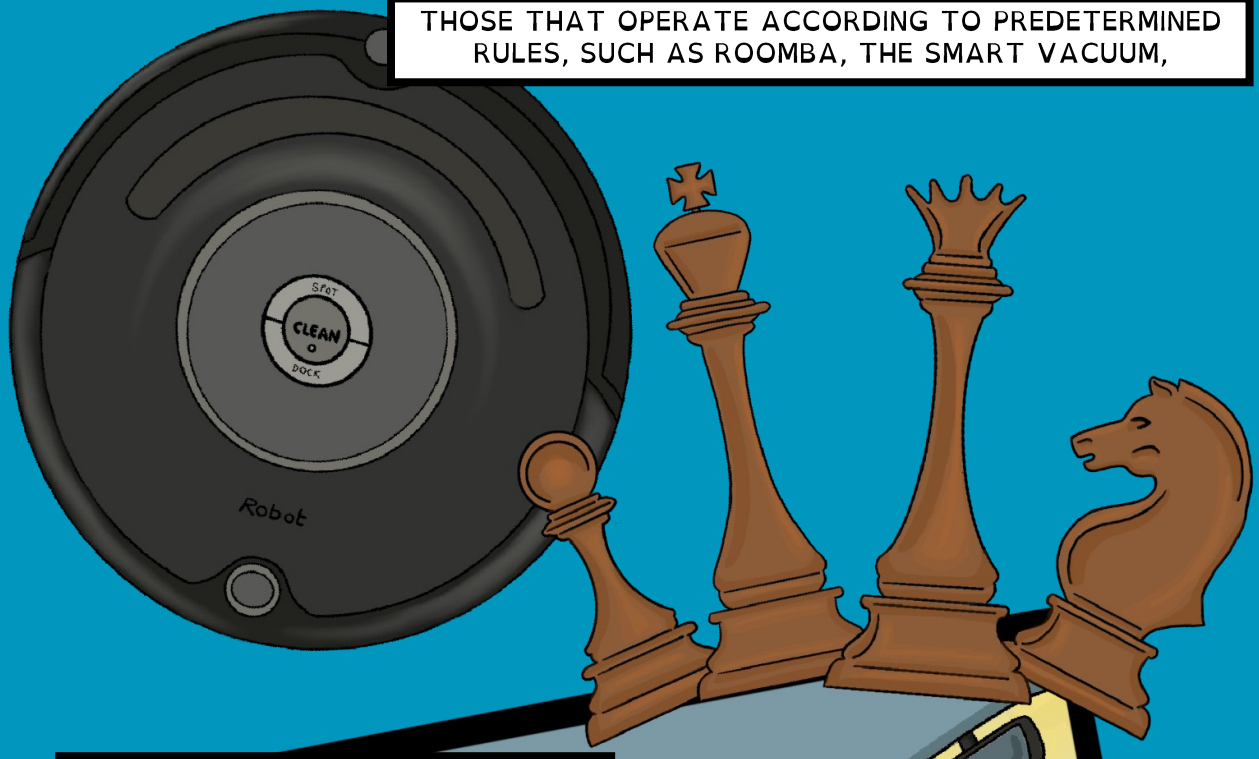
WHEN TALKING ABOUT ARTIFICIAL INTELLIGENCE (AI), WE USUALLY MAKE A DISTINCTION BETWEEN 'CLASSICAL AI' SYSTEMS -

THOSE THAT OPERATE ACCORDING TO PREDETERMINED RULES, SUCH AS ROOMBA, THE SMART VACUUM,



AND THOSE THAT 'LEARN' RULES FROM DATA -

SUCH AS CHESS-PLAYING AI

OR A SELF-DRIVING CAR

THIS DISTINCTION IS NOT STRICT.

IN FACT, MOST AI SYSTEMS OUT THERE IN THE WORLD TODAY COMBINE HAND-CRAFTED RULES WITH SOME FORM OF LEARNING.

LET'S SEE EXAMPLES OF SUCH RULES, AND SEE HOW MACHINES **LEARN THEM FROM DATA**!

SUPPOSE THAT YOU ARE TASKED WITH DESIGNING A SMART LIGHTING SYSTEM -

THAT AUTONOMOUSLY TURNS THE LIGHTS IN YOUR HOUSE ON AND OFF.

HOW SHOULD YOUR AI DECIDE WHEN TO TAKE THESE ACTIONS?

WE CAN START DESIGNING SUCH A SYSTEM BASED ON OUR OWN EVERYDAY 'INTELLIGENCE'.

LET'S CALL THIS **RULE 1**. IT SIMPLY SAYS –

TURN ON THE LIGHTS WHEN IT'S DARK OUTSIDE,

OTHERWISE KEEP THE LIGHTS OFF.

THIS ALGORITHM IS VERY SIMPLE, IT'S JUST ONE STEP –

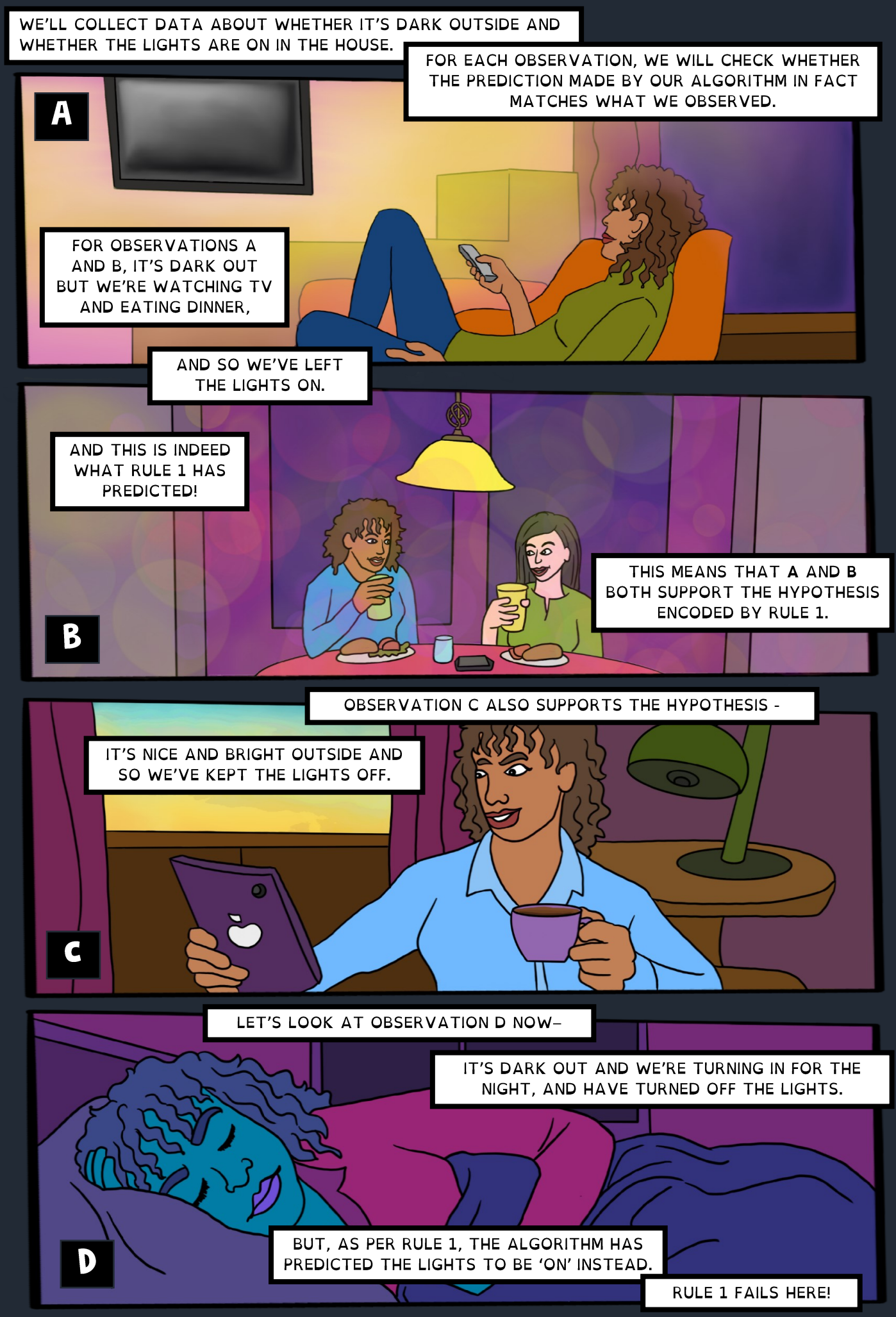
IT TAKES THE OUTSIDE CONDITIONS (WHETHER IT'S DARK OUTSIDE) AS AN INPUT,

AND USING RULE 1, PREDICTS THE APPROPRIATE OUTPUT - WHETHER TO TURN ON THE LIGHT.

THIS RULE IS SIMPLE, BUT IS IT ANY GOOD?

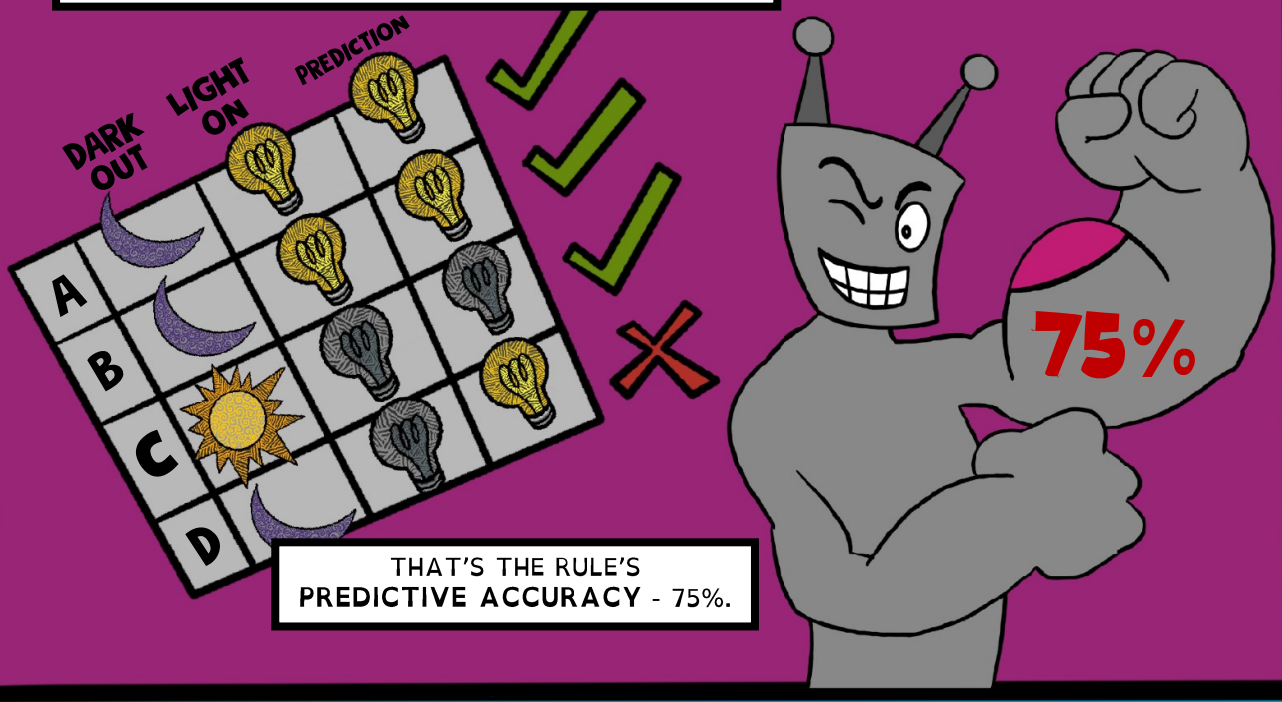
DOES IT APPROPRIATELY CAPTURE HOW YOU WOULD MANUALLY OPERATE THE LIGHTS IN YOUR HOUSE?

LET'S RUN AN EXPERIMENT TO FIND OUT!


WE'LL COLLECT DATA ABOUT WHETHER IT'S DARK OUTSIDE AND WHETHER THE LIGHTS ARE ON IN THE HOUSE.
FOR EACH OBSERVATION, WE WILL CHECK WHETHER THE PREDICTION MADE BY OUR ALGORITHM IN FACT MATCHES WHAT WE OBSERVED.
A
FOR OBSERVATIONS A AND B, IT'S DARK OUT BUT WE'RE WATCHING TV AND EATING DINNER,
AND SO WE'VE LEFT THE LIGHTS ON.
AND THIS IS INDEED WHAT RULE 1 HAS PREDICTED!
THIS MEANS THAT A AND B BOTH SUPPORT THE HYPOTHESIS ENCODED BY RULE 1.
B
OBSERVATION C ALSO SUPPORTS THE HYPOTHESIS -
IT'S NICE AND BRIGHT OUTSIDE AND SO WE'VE KEPT THE LIGHTS OFF.
C
LET'S LOOK AT OBSERVATION D NOW–
IT'S DARK OUT AND WE'RE TURNING IN FOR THE NIGHT, AND HAVE TURNED OFF THE LIGHTS.
BUT, AS PER RULE 1, THE ALGORITHM HAS PREDICTED THE LIGHTS TO BE 'ON' INSTEAD.
RULE 1 FAILS HERE!
D

LET'S LOOK AT WHAT WE'VE LEARNED ABOUT RULE 1 FROM OUR EXPERIMENT-

OUR RULE WAS ABLE TO PREDICT THE OUTPUT CORRECTLY 3 TIMES OUT OF 4.

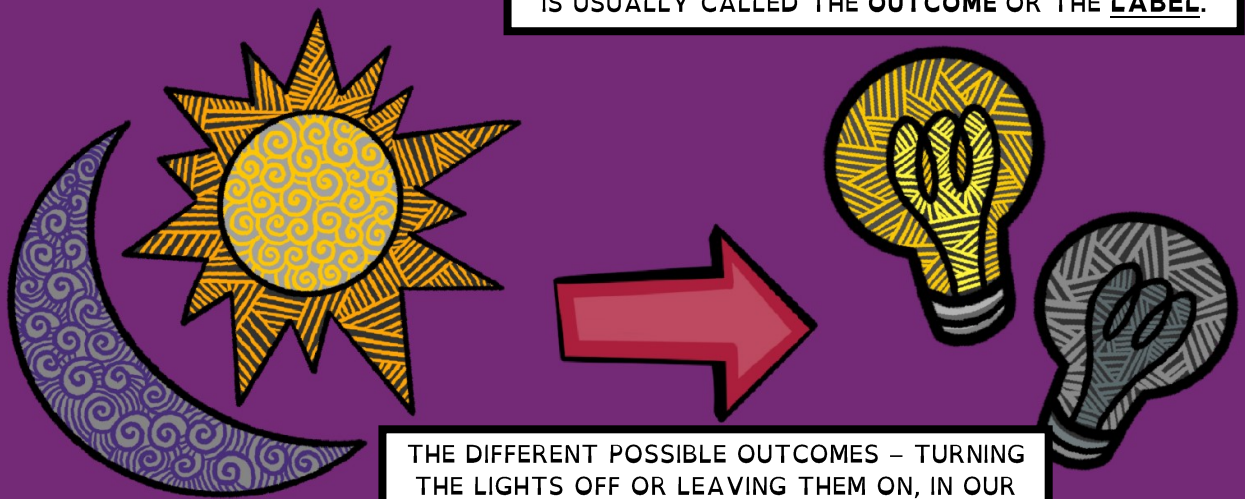


THAT'S THE RULE'S **PREDICTIVE ACCURACY** - 75%.

LET'S FIX SOME MORE TERMINOLOGY HERE -

IT'S CUSTOMARY TO REFER TO THE INPUT OF THE RULE - WHETHER IT'S DARK OUT, IN OUR EXAMPLE - AS THE INPUT FEATURE, OR JUST **FEATURE**.

THE OUTPUT – THE STATE OF OUR LIGHTS (ON/OFF) - IS USUALLY CALLED THE **OUTCOME** OR THE **LABEL**.



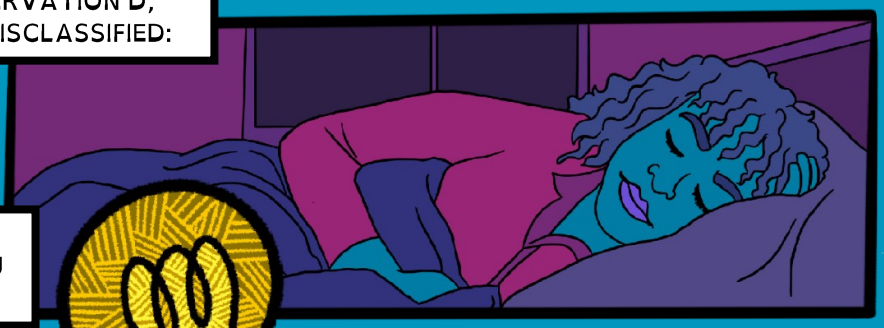
THE DIFFERENT POSSIBLE OUTCOMES – TURNING THE LIGHTS OFF OR LEAVING THEM ON, IN OUR EXAMPLE - ARE CALLED '**CLASSES**'.

THE RULE WE ARE WORKING WITH IS CALLED A '**CLASSIFIER**' – IT ASSIGNS A CLASS LABEL TO AN OBSERVATION.

THE CLASSIFIER WE DESIGNED USING RULE 1 CAN MAKE ONE OF TWO CHOICES – TURN THE LIGHTS EITHER ON OR OFF.

WE CALL SUCH CLASSIFIERS '**BINARY**'.

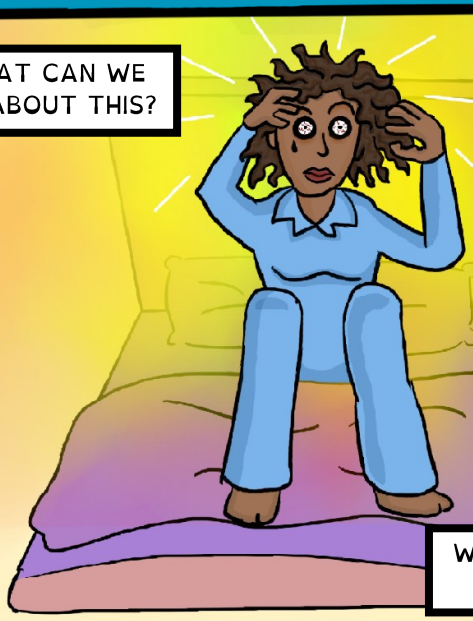
BACK TO OBSERVATION D, WHICH RULE 1 MISCLASSIFIED:

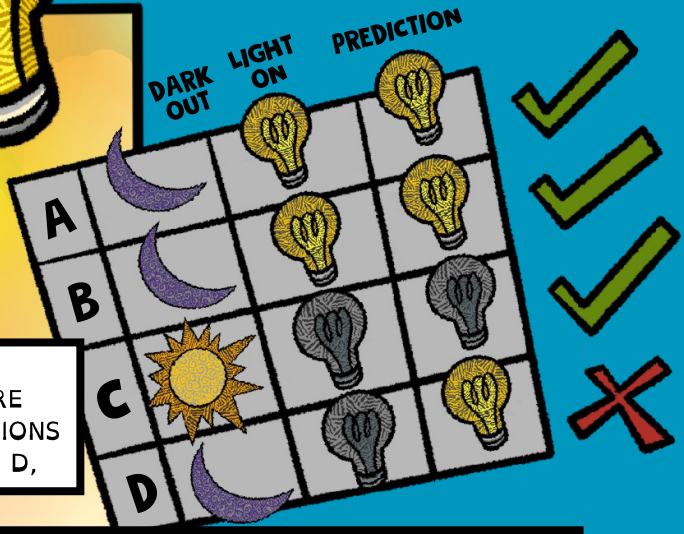


WHAT IS THE COST OF THIS MISTAKE?

AS YOU PROBABLY GUESSED, IT'S THAT THE SMART LIGHT WOKE YOU UP IN THE MIDDLE OF THE NIGHT!

WHAT CAN WE DO ABOUT THIS?





IF WE COMPARE OBSERVATIONS A, B AND D,

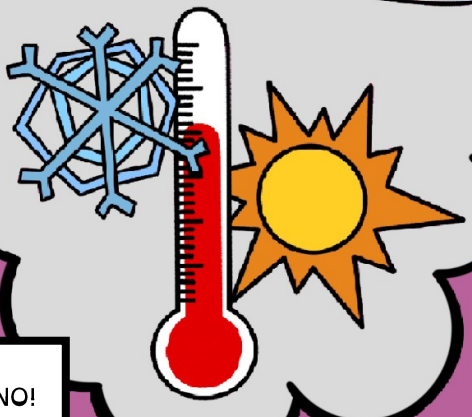
WE SEE THAT THEY HAVE THE SAME VALUE OF THE INPUT FEATURE (IT'S DARK OUT), BUT DIFFERENT OUTPUTS.

THIS MAKES US THINK THAT WE NEED SOME ADDITIONAL FEATURES TO DISTINGUISH BETWEEN THESE SITUATIONS.

NOW, A DECISION THAT YOU, AS THE DESIGNER OF THIS SYSTEM, HAVE TO MAKE IS:

WHAT ARE SOME OTHER INPUTS THAT MAY BE USEFUL?

BASED ON YOUR EXPERIENCE, WHAT FEATURES DO YOU THINK WILL BE HELPFUL IN PREDICTING THE OUTCOME?



THE OUTSIDE TEMPERATURE? NO!

THE PRICE OF TEA IN CHINA? NO!

WELL, WHAT ABOUT - WHETHER IT'S BEDTIME?

LET'S GET TO WORK TO REFINE OUR RULE!

HERE'S OUR REFINED RULE –

WE'LL CALL IT **RULE 2**

"TURN ON THE LIGHTS IF IT'S DARK OUTSIDE,

AND IT'S NOT YET BEDTIME.

OTHERWISE KEEP THE LIGHTS OFF."

E

VOILA! IT SEEMS TO BE WORKING PERFECTLY –

LET'S RE-RUN OUR EXPERIMENT, COLLECT SOME MORE OBSERVATIONS AND EVALUATE OUR NEW RULE.

F

G

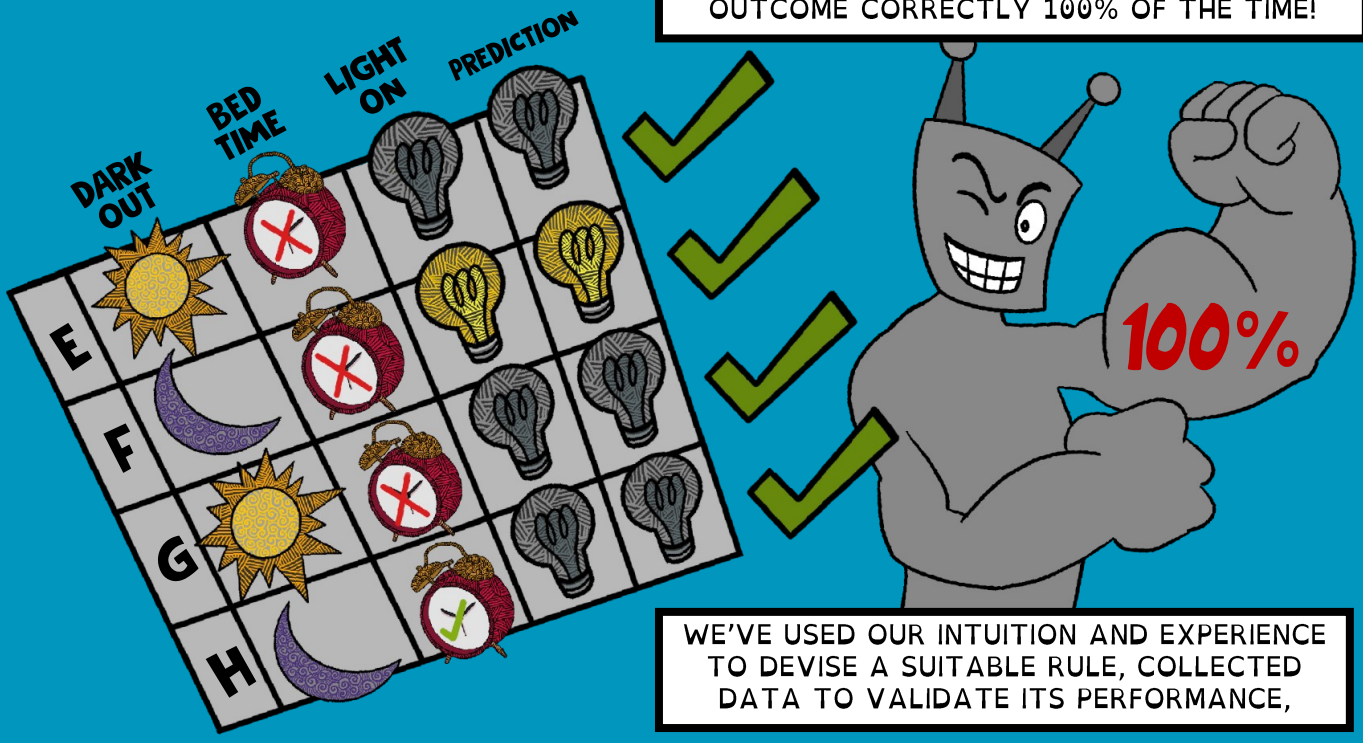
WE DON'T NEED THE LIGHTS ON UNLESS IT'S DARK OUTSIDE AND WE'RE AWAKE DOING SOMETHING!

H

AND LOOK, THIS TIME IT'S TURNING OFF THE LIGHTS FOR US IF WE FALL ASLEEP ON THE COUCH (PAST OUR BEDTIME) – SO CARING!

RULE 2 HAS SHOWN PERFECT ACCURACY -

OUR ALGORITHM IS ABLE TO PREDICT THE OUTCOME CORRECTLY 100% OF THE TIME!



WE'VE USED OUR INTUITION AND EXPERIENCE TO DEVISE A SUITABLE RULE, COLLECTED DATA TO VALIDATE ITS PERFORMANCE,

AND MADE THE NECESSARY ADJUSTMENTS UNTIL WE REACHED A PERFORMANCE THAT WE'RE HAPPY WITH!

IN FACT, WE ARE SO HAPPY WITH OUR SMART LIGHT

— WITH HOW CONVENIENT IT IS, AND HOW IT'S HELPING US CONSERVE ENERGY —

THAT WE WANT TO OFFER IT TO OTHERS TO USE.

LET'S SEE IF IT WORKS FOR OUR FRIEND ANN TO USE AT HER OFFICE.

BUT BEFORE WE GO AHEAD AND REWIRE ANN'S ENTIRE OFFICE BUILDING, LET'S COLLECT SOME USAGE PATTERNS TO SEE WHETHER OUR RULE WOULD BE EFFECTIVE.

YOU KNOW THE DRILL – LET'S RUN AN EXPERIMENT!

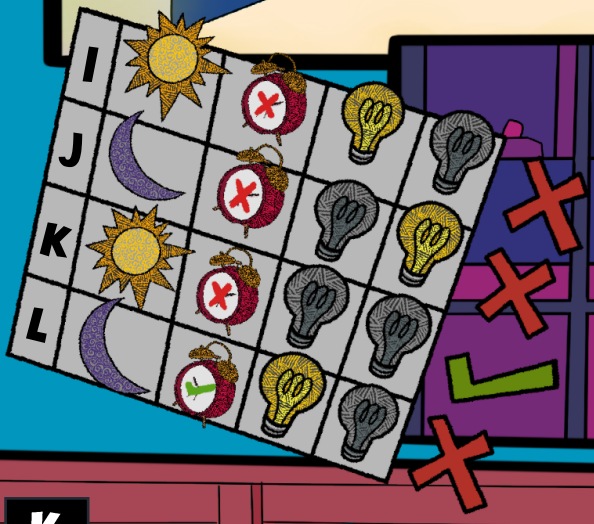
RECALL **RULE 2 -**

"TURN ON THE LIGHTS IF IT'S DARK OUTSIDE, AND IT'S NOT YET BEDTIME. OTHERWISE KEEP THE LIGHTS OFF."

I

AT THE OFFICE, WE KEEP THE LIGHTS ON THROUGH THE DAY WHEN PEOPLE ARE WORKING.

BUT RULE 2 WOULD INCORRECTLY TURN THEM OFF, SINCE IT'S BRIGHT OUTSIDE



J

MOST EVENINGS, WHEN EVERYONE'S GONE HOME, THE LIGHTS ARE TURNED OFF.

K

BUT RULE 2 WOULD INCORRECTLY TURN THEM ON, SINCE IT'S DARK OUT!

ON WEEKENDS, THE OFFICE IS EMPTY AND SO THE LIGHTS ARE OFF THROUGHOUT THE DAY!

L

IN THIS CASE, RULE 2 WORKS CORRECTLY – IT KEEPS THE LIGHTS OFF, SINCE IT IS BRIGHT OUTSIDE.

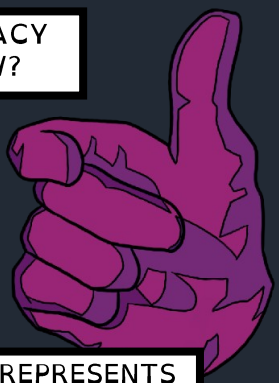
EVERY SO OFTEN SOMEONE STAYS LATE AT THE OFFICE, FINISHING UP DELIVERABLES IN TIME FOR A CRITICAL DEADLINE.

WE NEED THE LIGHTS ON IN THIS SCENARIO, BUT RULE 2 IS WRONG AGAIN- IT WOULD TURN THE LIGHTS OFF, SINCE IT'S LATE (PAST OUR USUAL BEDTIME).

OH, NO! THAT MEANS WE ONLY GOT 1 CORRECT PREDICTION OUT OF 4!

IF WE ASSUME THAT LIGHTS ARE ON ABOUT HALF THE TIME, WE WOULD HAVE DONE BETTER HAD WE JUST FLIPPED A COIN TO DECIDE WHETHER TO TURN ON THE LIGHTS!

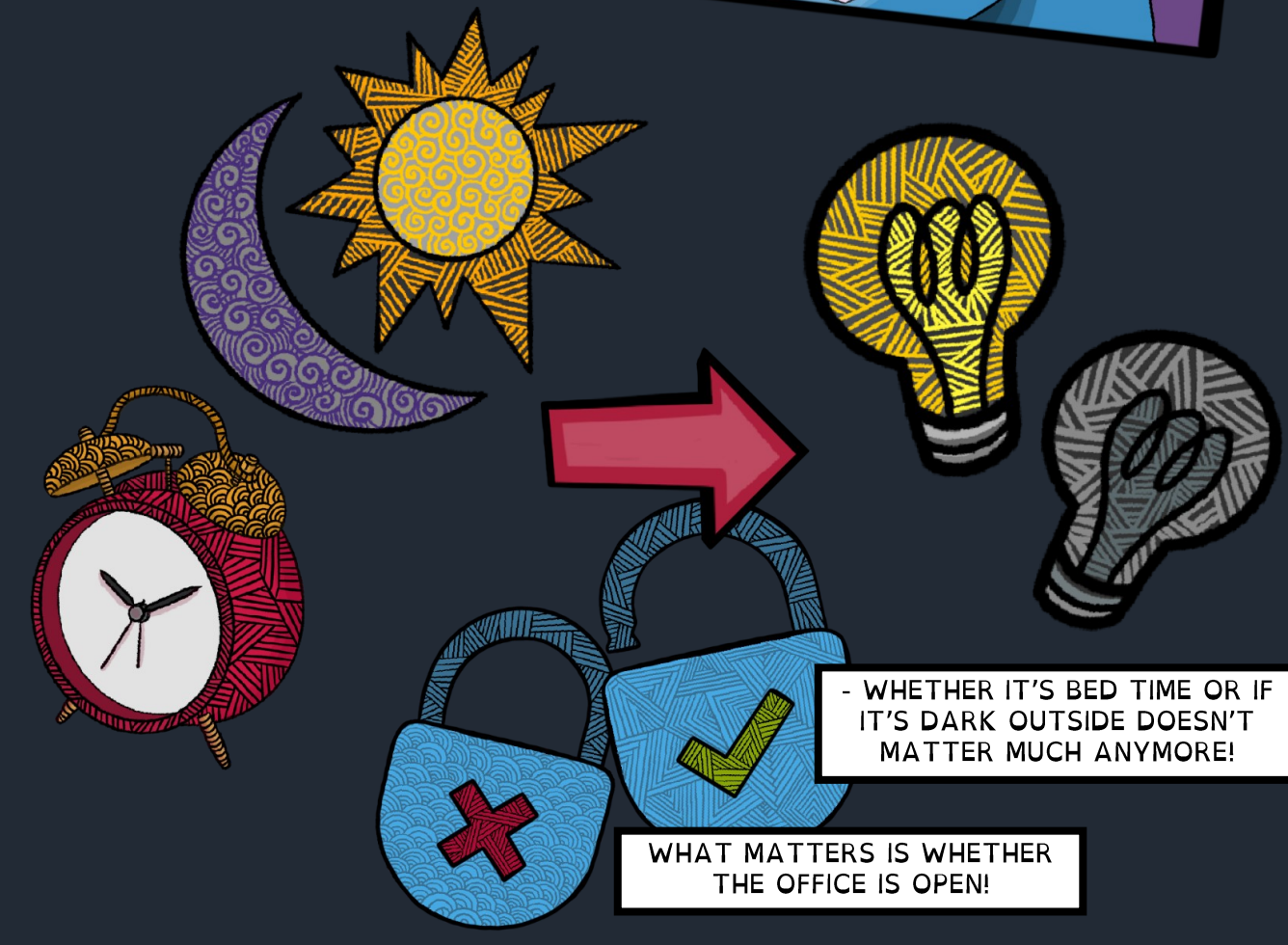
WHY IS THE ACCURACY OF RULE 2 SO LOW?



BECAUSE THE DATASET ON WHICH WE TESTED THE CLASSIFIER REPRESENTS A DIFFERENT SITUATION THAN THE DATASET ON WHICH WE TRAINED IT.

WE **'TRAINED'** THE CLASSIFIER – DECIDED ON THE APPROPRIATE RULES – BASED ON OUR CONSUMPTION PATTERNS AT HOME,

BUT ANN **'TESTED'** IT AT HER OFFICE.



- WHETHER IT'S BED TIME OR IF IT'S DARK OUTSIDE DOESN'T MATTER MUCH ANYMORE!

WHAT MATTERS IS WHETHER THE OFFICE IS OPEN!

WHAT'S THE COST OF A MISTAKE HERE?

THE COST OF A **FALSE POSITIVE** - UNNECESSARILY TURNING ON THE LIGHT WHEN IT SHOULD BE OFF - IS THAT WE WASTE ENERGY AND ROLL UP A HEFTY BILL FOR THE COMPANY.

THE COST OF A **FALSE NEGATIVE** - TURNING OFF THE LIGHT WHEN IT'S NEEDED — IS THAT WE KEEP INTERRUPTING PEOPLE IN THE MIDDLE OF THEIR WORK AND THEIR PRODUCTIVITY SUFFERS.

WHAT SHOULD WE DO? GO BACK TO THE DRAWING BOARD AG

THINK ABOUT WHAT ADDITIONAL FEATURES TO USE, COLLECT THAT DATA,

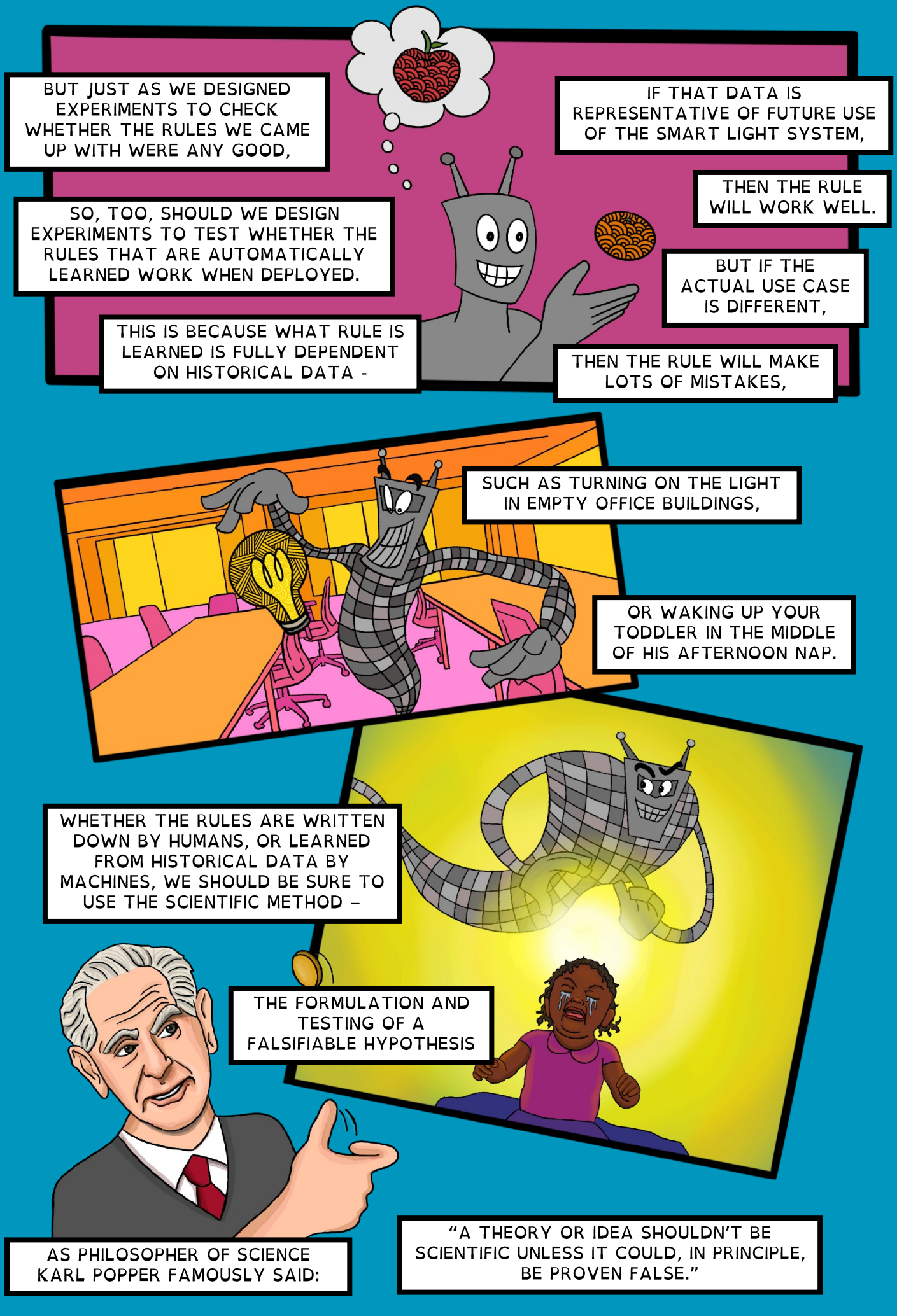
AND RUN AN EXPERIMENT TO CHECK WHETHER OUR RULE IN FACT WORKS?

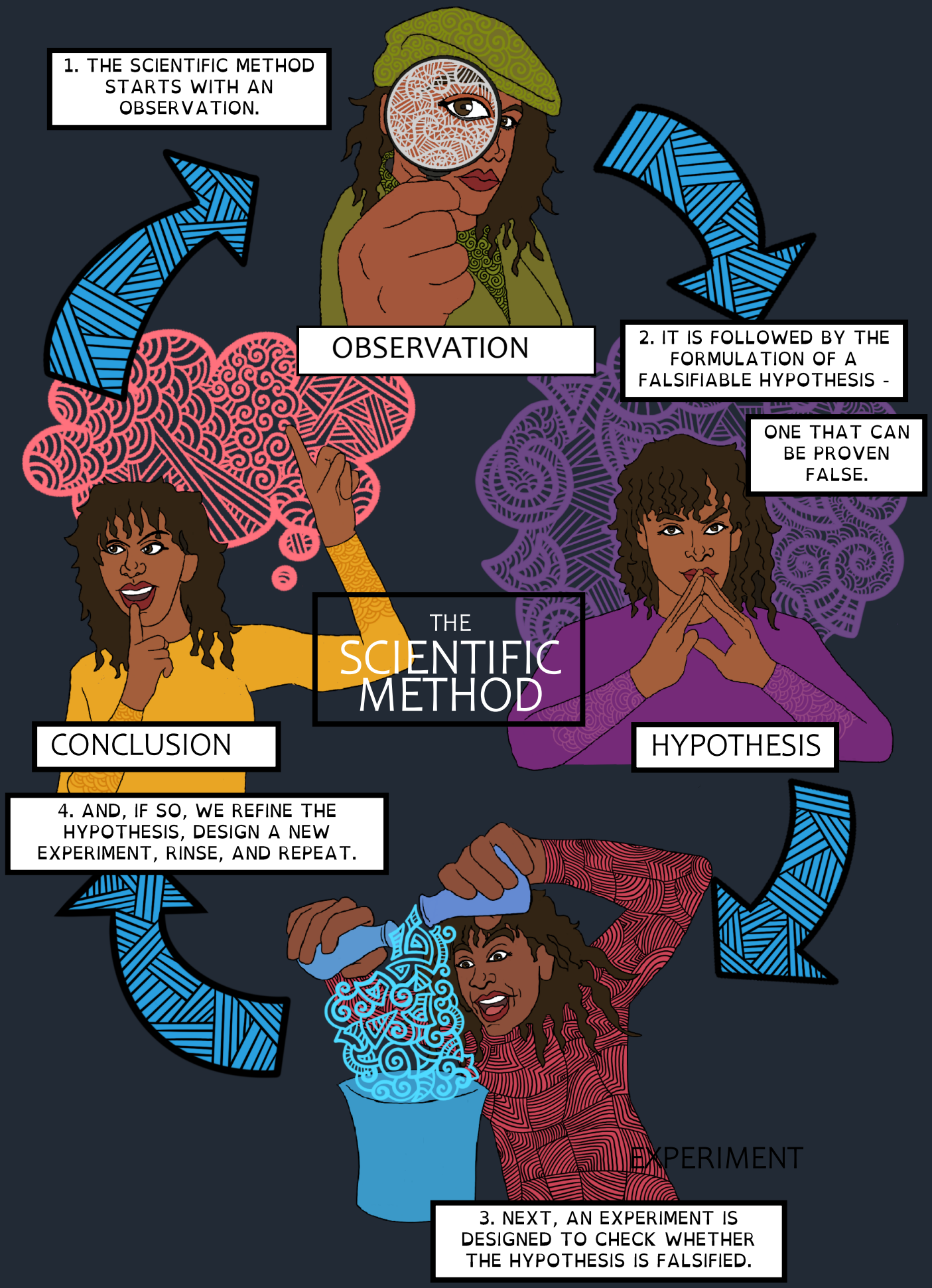
BUT THIS IS TEDIOUS!

AND MOST IMPORTANTLY - WILL BE VERY HARD FOR U TO CONTINUE DERIVING THESE RULES THAT ARE GETTING MORE AND MORE COMPLEX,

DEPENDING ON THE LOCATIONS W THE SMART LIGHT IS USED, AN DIFFERENT REQUIREME

THE ANSW STATISTICAL P

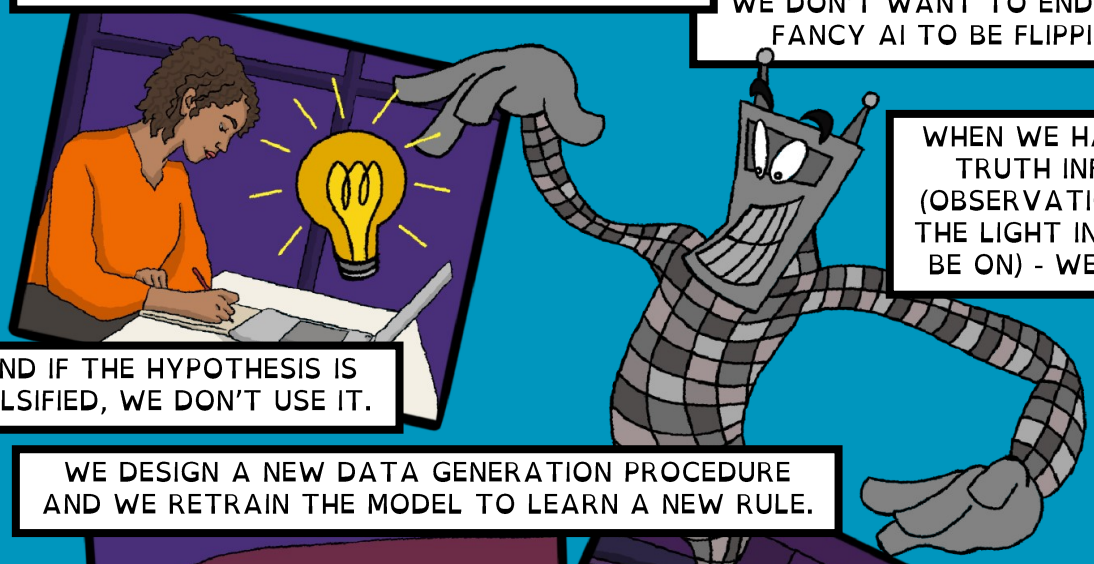

BUT JUST AS WE DESIGNED EXPERIMENTS TO CHECK WHETHER THE RULES WE CAME UP WITH WERE ANY GOOD,
SO, TOO, SHOULD WE DESIGN EXPERIMENTS TO TEST WHETHER THE RULES THAT ARE AUTOMATICALLY LEARNED WORK WHEN DEPLOYED.
THIS IS BECAUSE WHAT RULE IS LEARNED IS FULLY DEPENDENT ON HISTORICAL DATA -
IF THAT DATA IS REPRESENTATIVE OF FUTURE USE OF THE SMART LIGHT SYSTEM,
THEN THE RULE WILL WORK WELL.
BUT IF THE ACTUAL USE CASE IS DIFFERENT,
THEN THE RULE WILL MAKE LOTS OF MISTAKES,
SUCH AS TURNING ON THE LIGHT IN EMPTY OFFICE BUILDINGS,
OR WAKING UP YOUR TODDLER IN THE MIDDLE OF HIS AFTERNOON NAP.
WHETHER THE RULES ARE WRITTEN DOWN BY HUMANS, OR LEARNED FROM HISTORICAL DATA BY MACHINES, WE SHOULD BE SURE TO USE THE SCIENTIFIC METHOD –
THE FORMULATION AND TESTING OF A FALSIFIABLE HYPOTHESIS
AS PHILOSOPHER OF SCIENCE KARL POPPER FAMOUSLY SAID:
“A THEORY OR IDEA SHOULDN’T BE SCIENTIFIC UNLESS IT COULD, IN PRINCIPLE, BE PROVEN FALSE.”


1. THE SCIENTIFIC METHOD STARTS WITH AN OBSERVATION.
OBSERVATION
2. IT IS FOLLOWED BY THE FORMULATION OF A FALSIFIABLE HYPOTHESIS -
ONE THAT CAN BE PROVEN FALSE.
HYPOTHESIS
3. NEXT, AN EXPERIMENT IS DESIGNED TO CHECK WHETHER THE HYPOTHESIS IS FALSIFIED.
EXPERIMENT
4. AND, IF SO, WE REFINE THE HYPOTHESIS, DESIGN A NEW EXPERIMENT, RINSE, AND REPEAT.
CONCLUSION
THE SCIENTIFIC METHOD

THE CRUCIAL QUESTION: "DOES THE CLASSIFIER WORK?" IS FORMALIZED AS "ARE THE CLASSIFIER'S PREDICTIONS MORE ACCURATE THAN A RANDOM GUESS"?

THIS IS THE LOWEST BAR FOR ACCURACY –

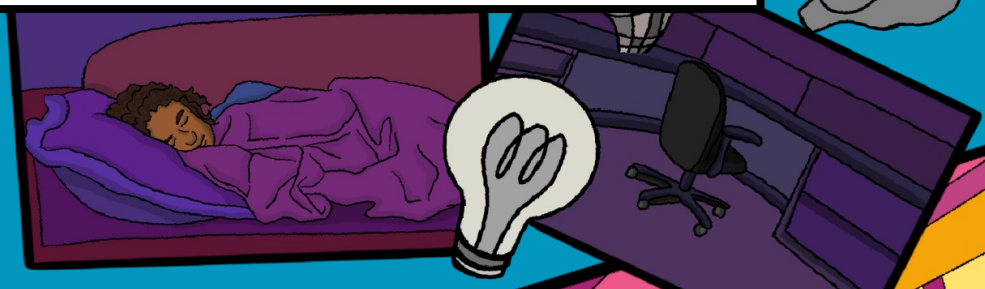
WE DON'T WANT TO END UP BUILDING FANCY AI TO BE FLIPPING COINS.



WHEN WE HAVE GROUND-TRUTH INFORMATION (OBSERVATIONS OF WHEN THE LIGHT INDEED SHOULD BE ON) - WE CAN CHECK.

AND IF THE HYPOTHESIS IS FALSIFIED, WE DON'T USE IT.

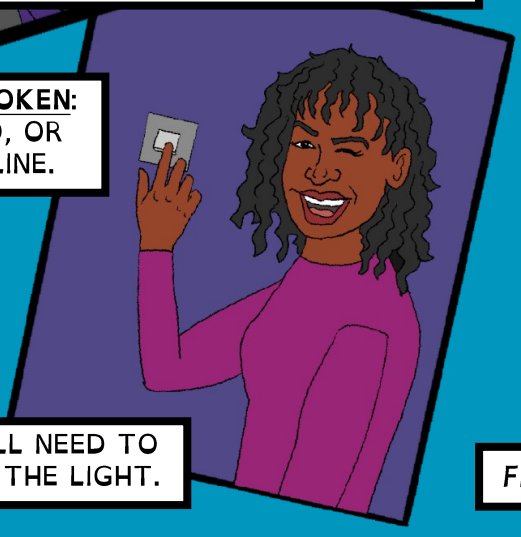
WE DESIGN A NEW DATA GENERATION PROCEDURE AND WE RETRAIN THE MODEL TO LEARN A NEW RULE.



IMPORTANTLY, EVEN WITH ALL THIS ADDITIONAL SOPHISTICATION, IT IS STILL UNLIKELY THAT WE'LL SEE PERFECT ACCURACY.

ONE OF THE REASONS FOR THIS IS THAT THERE IS **UNCERTAINTY** IN THE WORLD.

AND ANOTHER IS THAT **RULES ARE SOMETIMES BROKEN**: PEOPLE MAY COME TO WORK OVER THE WEEKEND, OR THEY STAY AT WORK LONGER TO MEET A DEADLINE.



AND SO THE BEST WE CAN HOPE FOR, IN REAL-LIFE SITUATIONS, IS THAT THE CLASSIFIER WILL WORK MOST OF THE TIME.

BUT ONCE IN A WHILE, SOMEONE WILL NEED TO GET UP AND TURN ON OR TURN OFF THE LIGHT.

FIN.