# measuring and experimenting

prof. dr. nicolas meseth

1. measuring settles it
2. know what you measure
3. one reading is a guess
4. build evidence

part 1

# measuring settles it

# which one lands first?

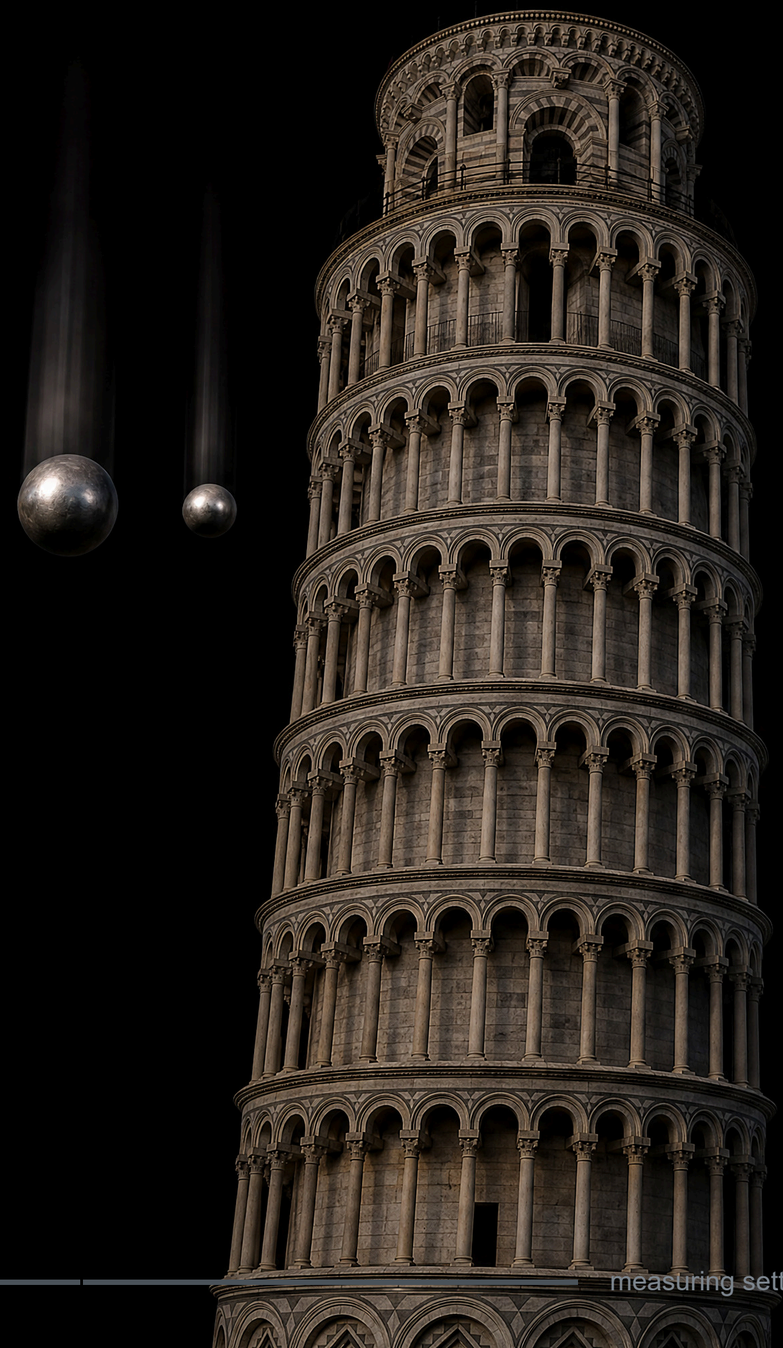


image: ai-generated (gpt-image-2)

# three ways to answer the same question

it sounds right

longer readings
collect more light

three ways to answer the same question

it sounds right

longer readings
collect more light

the assistant predicts it

`double the integration time`

three ways to answer the same question

it sounds right

longer readings
collect more light



the assistant predicts it

`double the integration time`



the series shows it

`41 / 50 → 47 / 50 recognised correctly`



evidence from your setup

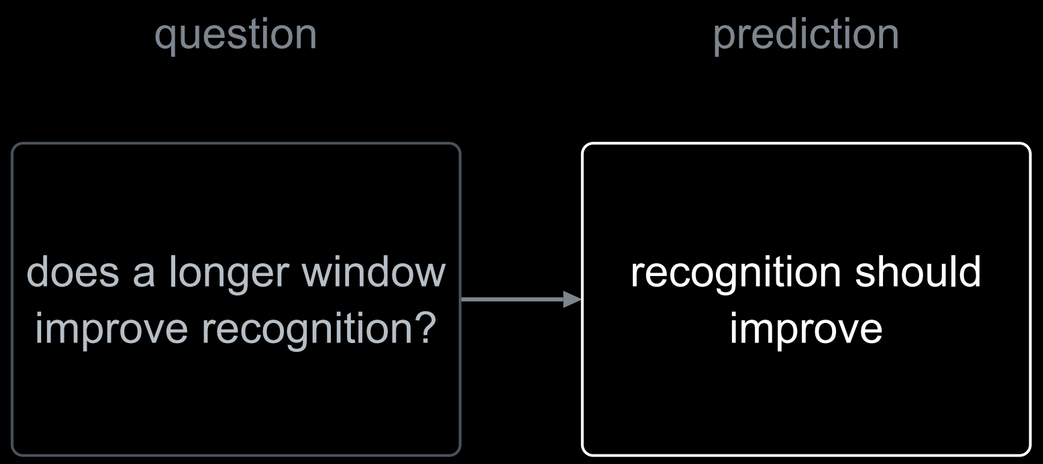
an explanation only claims something, while a measurement can decide it.

turn a claim into a test

question

does a longer window improve recognition?

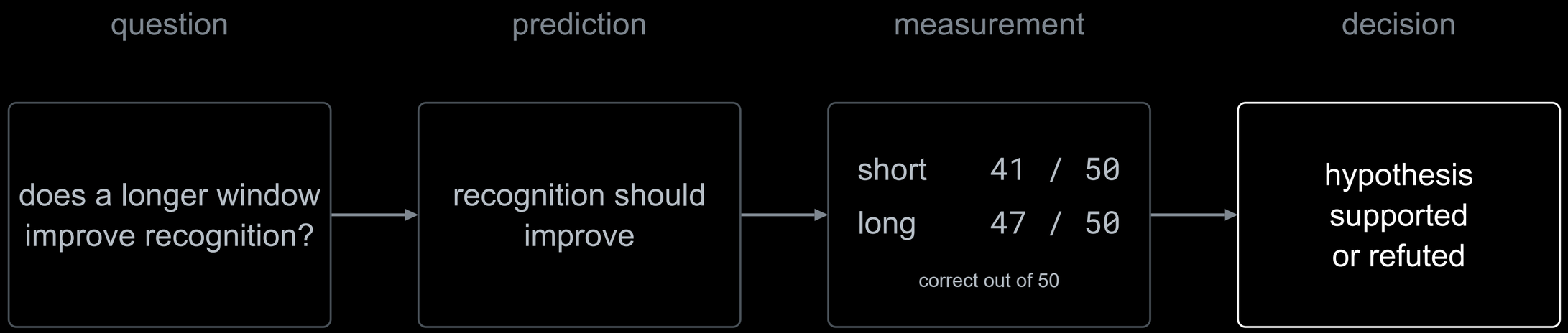
# turn a claim into a test



# turn a claim into a test



# turn a claim into a test




write the expectation before you measure.

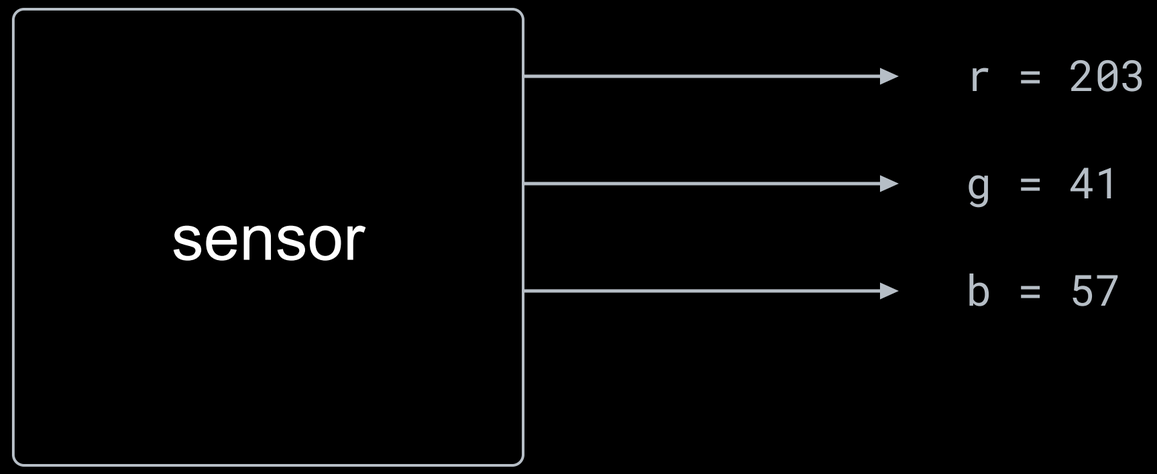
part 2

# know what you measure

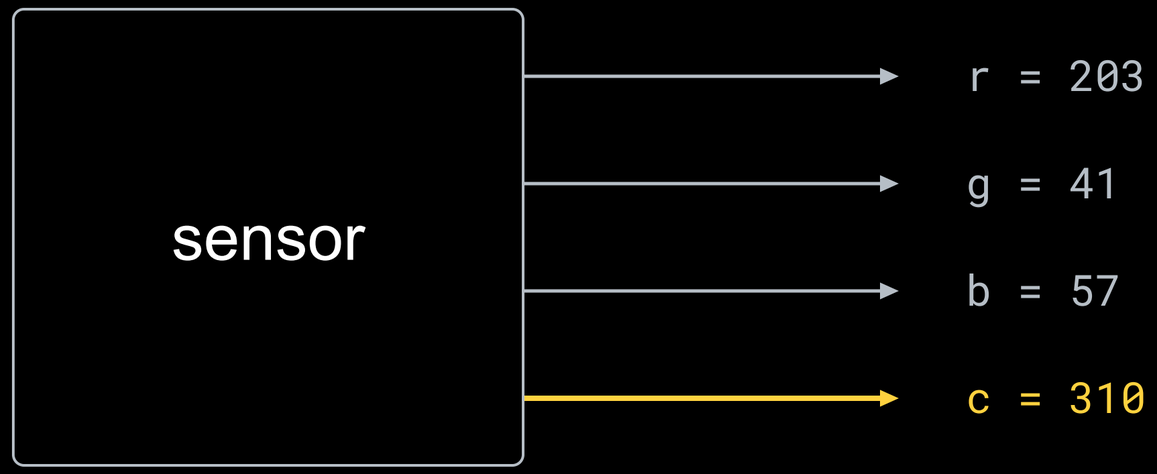
this concept lives at the input



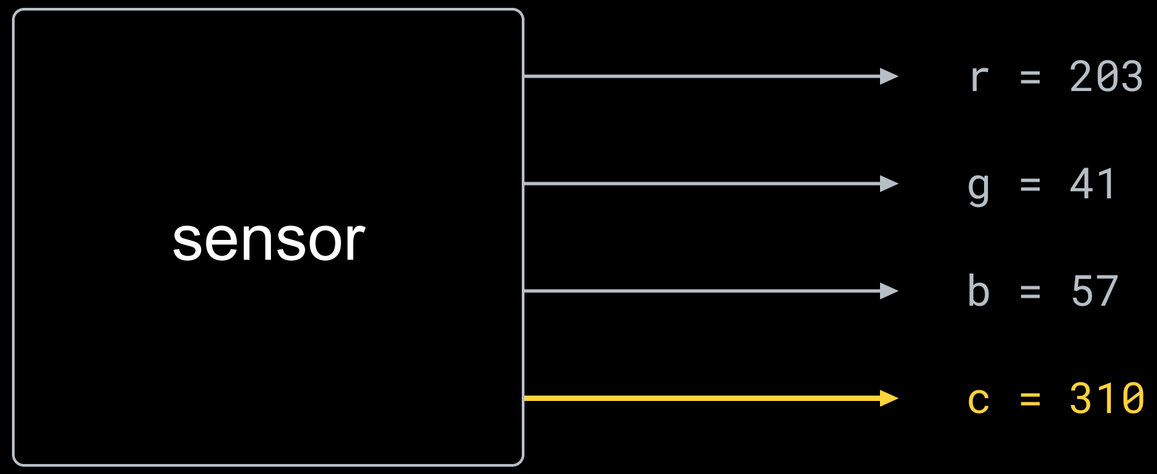
the sensor returns four numbers



the sensor returns four numbers



the sensor returns four numbers




`clear`

no colour filter

most sensitive

your eyes see a colour, but the program only sees four numbers.

sent is not measured

what you send

```
r = 255
g =   0
b =   0
```

sent is not measured

what you send

```
r = 255
g =   0
b =   0
```



what arrives

```
r = 203
g =  41
b =  57
c = 310
```

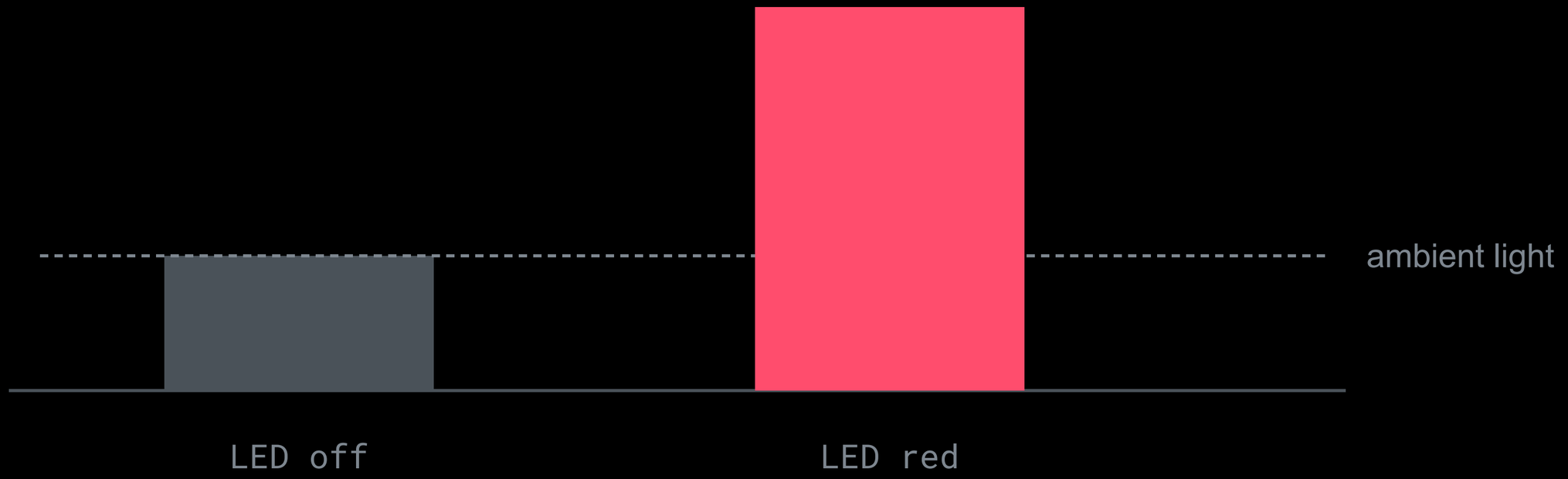
the filters overlap, distance dims the light, and the room shines in too

the numbers differ from what was sent, and that is normal, not a defect.

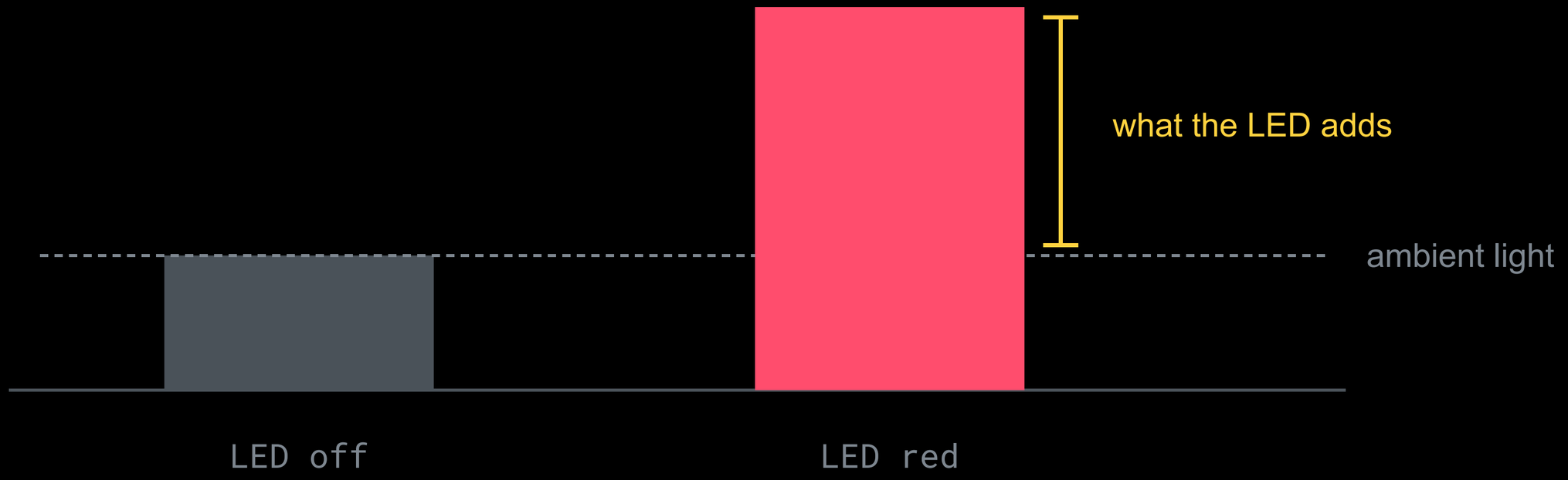
# measure the dark first



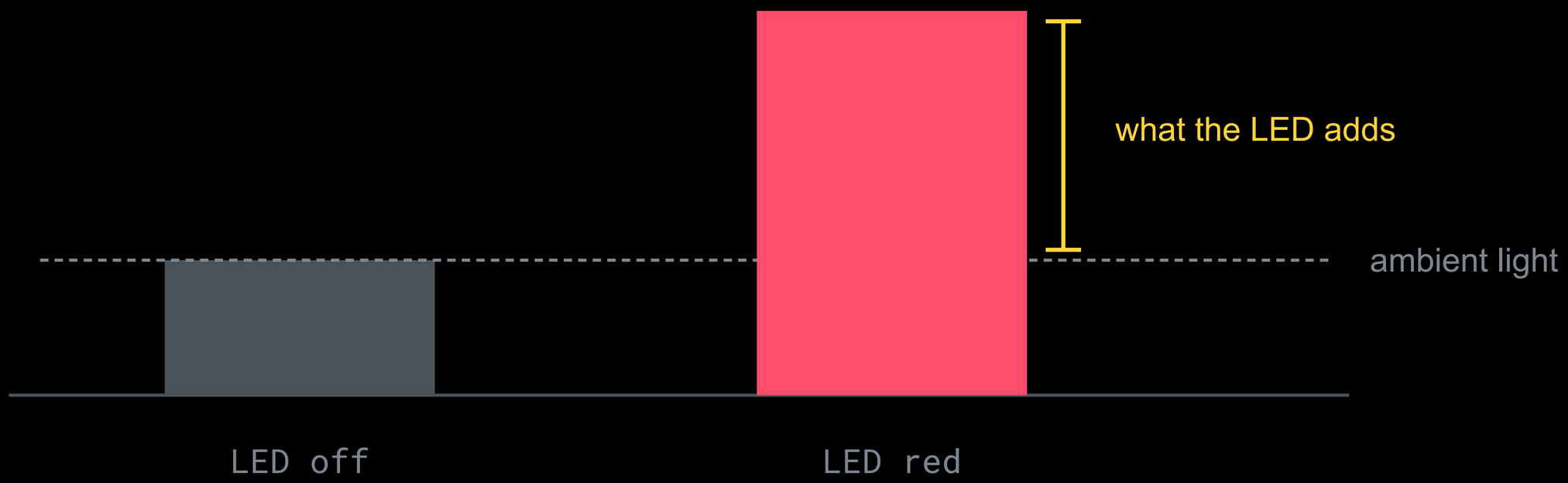
measure the dark first



measure the dark first



# measure the dark first




```
reading = ambient + LED + noise
```

part 3

# one reading is a guess

which value is true?

198

which value is true?

198

205

one reading is a guess

which value is true?

198 205 201 195 206

which value is true?

198 205 201 195 206

same LED · same settings · five readings

one reading is a guess

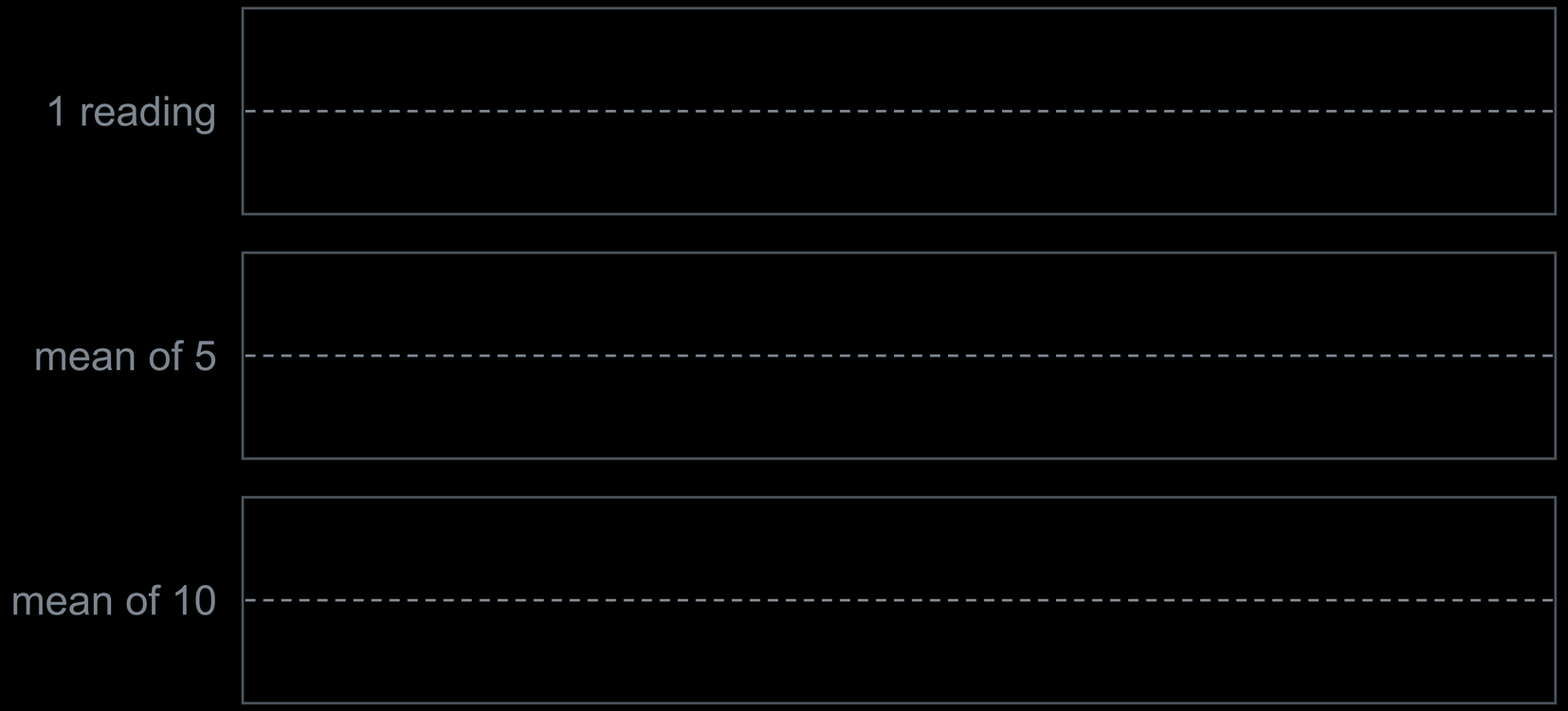
which value is true?

198 205 201 195 206

same LED · same settings · five readings

all of them are measurements

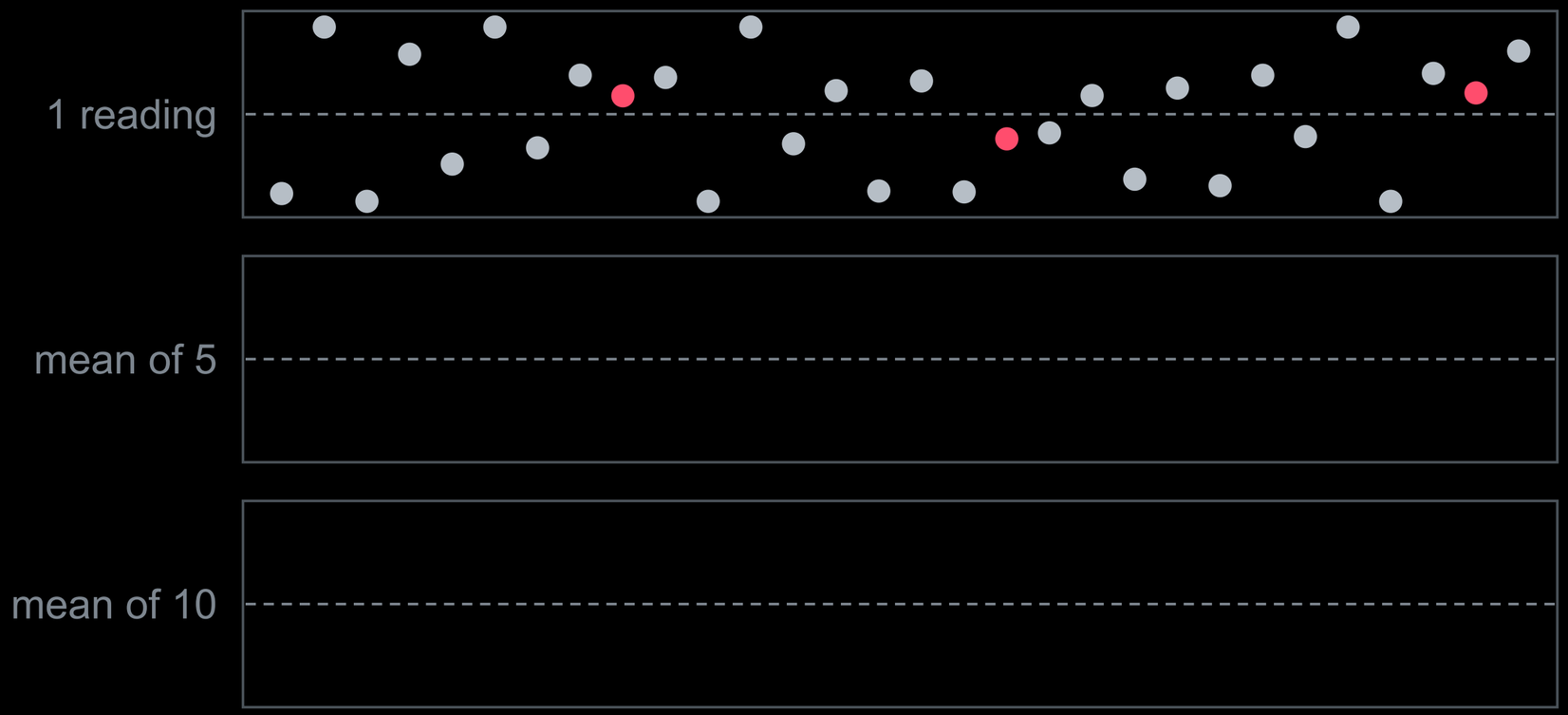
how many readings per decision?




a dot on the wrong side of the dashed threshold is a wrong decision

one reading is a guess

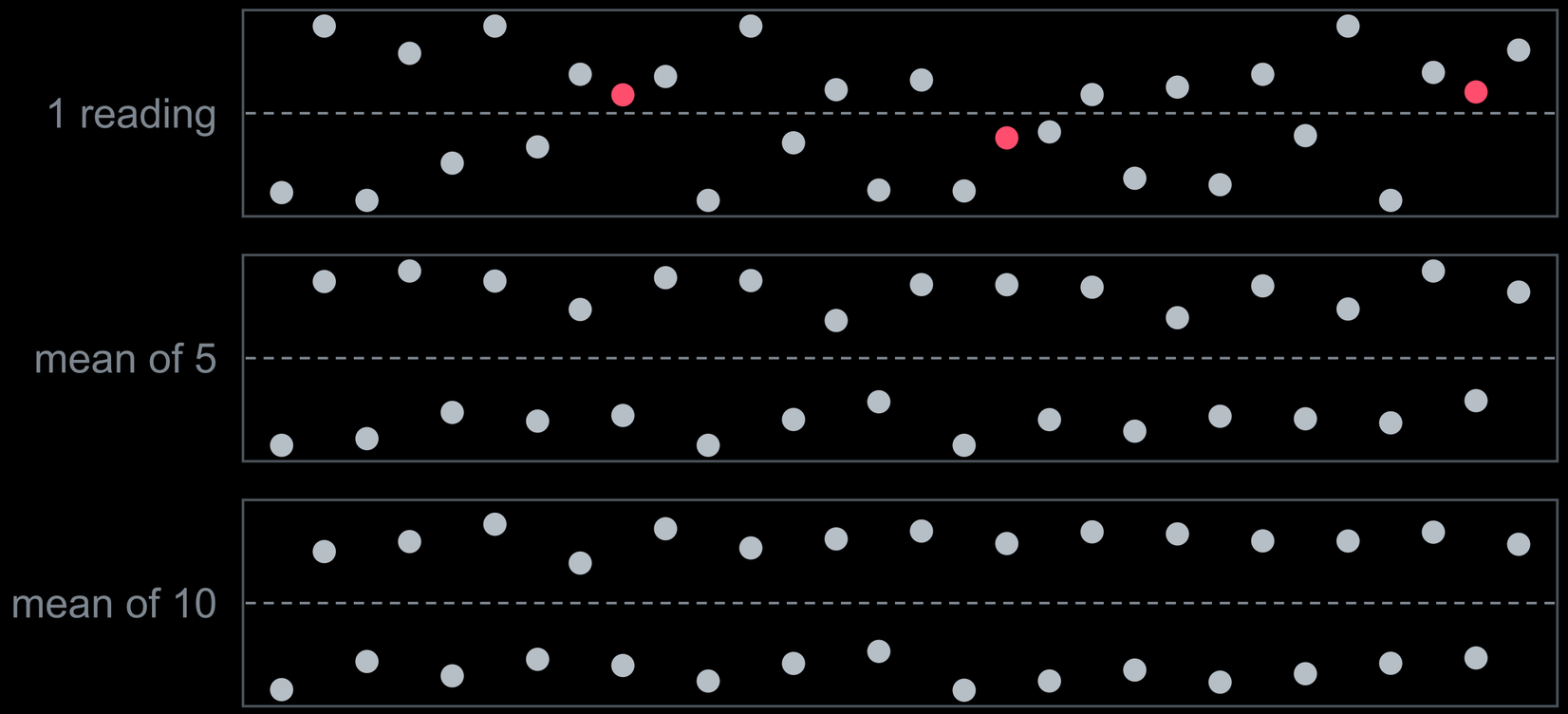
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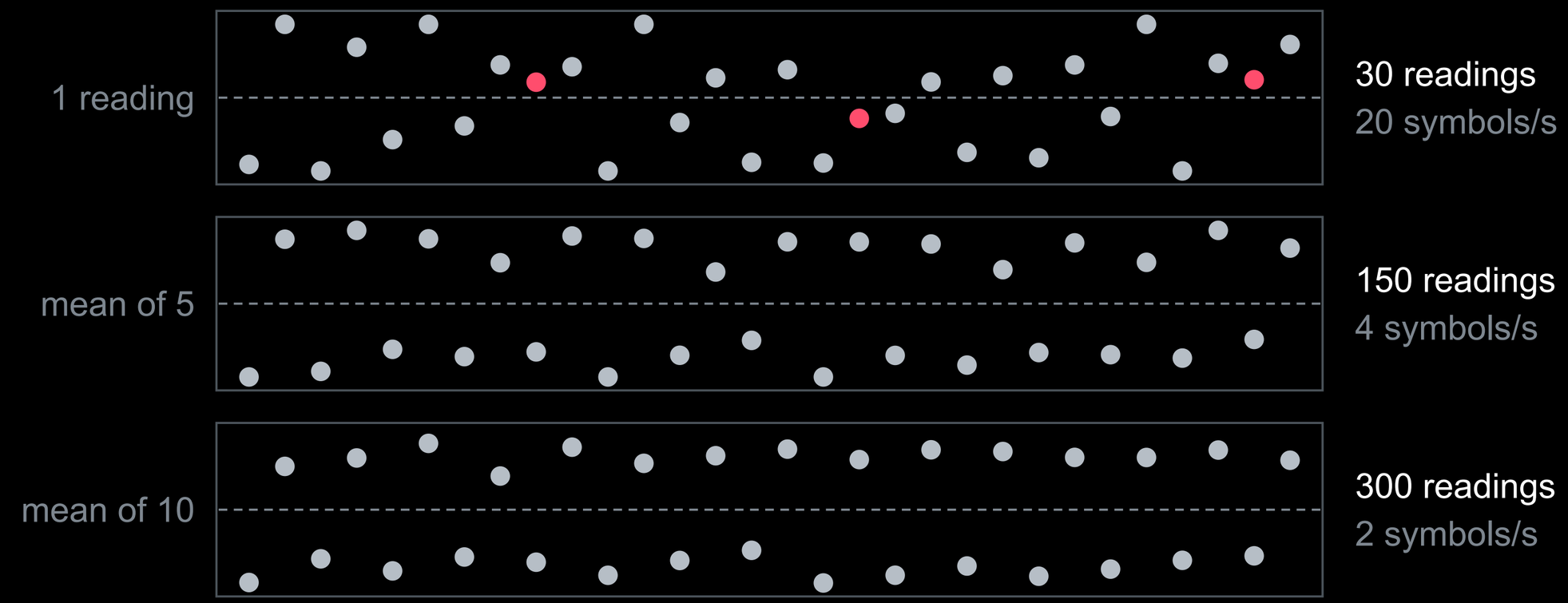
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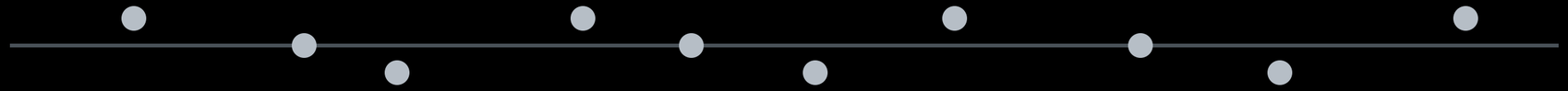



a dot on the wrong side of the dashed threshold is a wrong decision

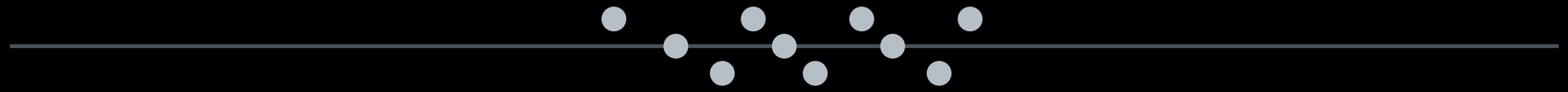
averaging lowers the error rate, but you pay for it with speed.

a series reveals what one reading hides

individual readings

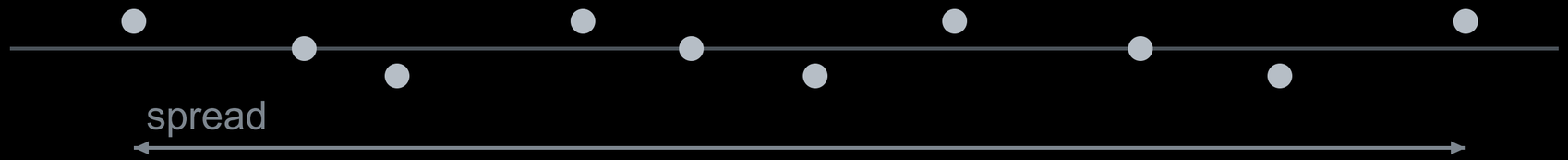


averages of five

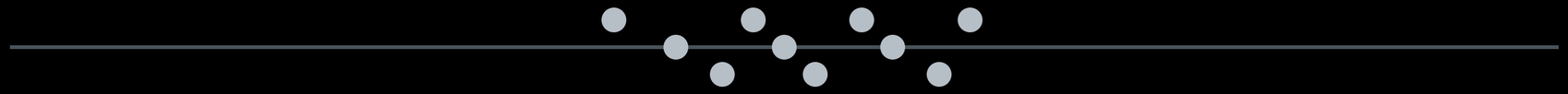


# a series reveals what one reading hides

individual readings

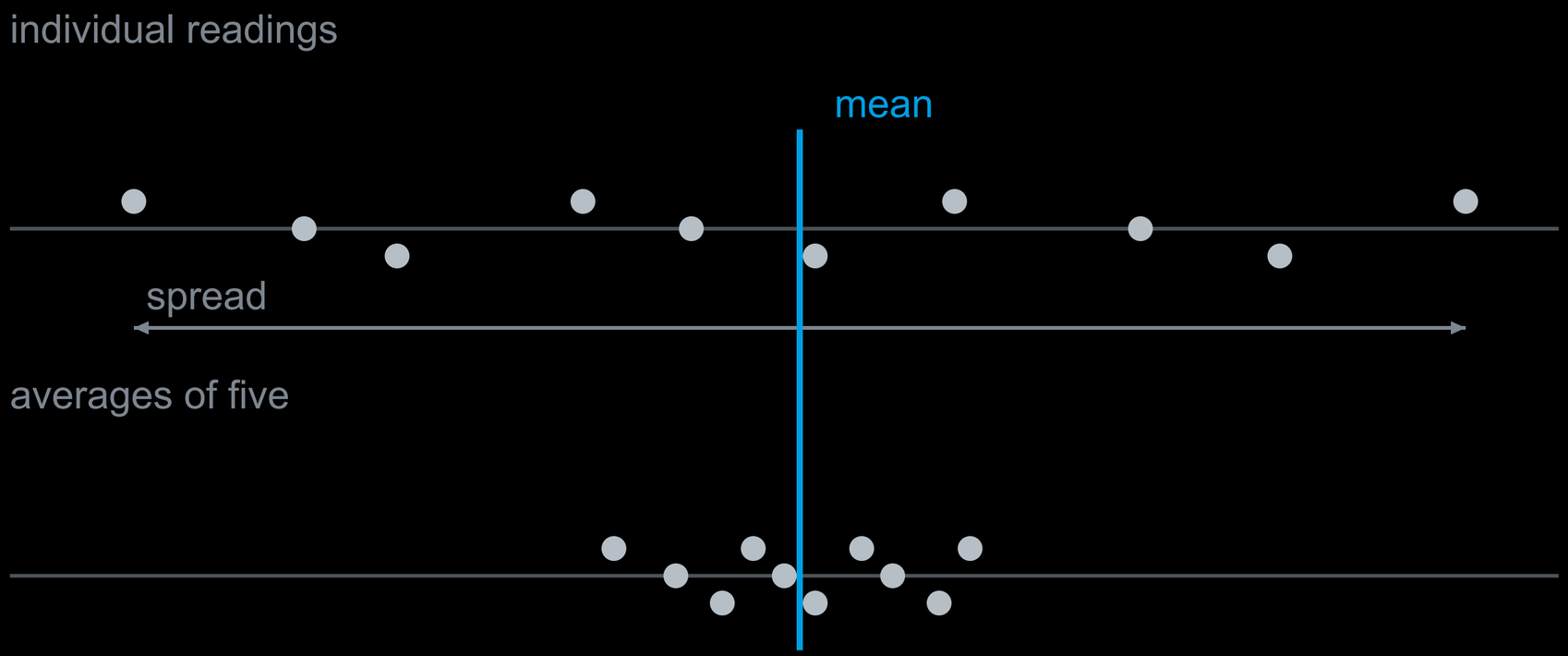



averages of five



one reading is a guess

a series reveals what one reading hides




report the centre and the spread.

# the knob: integration time



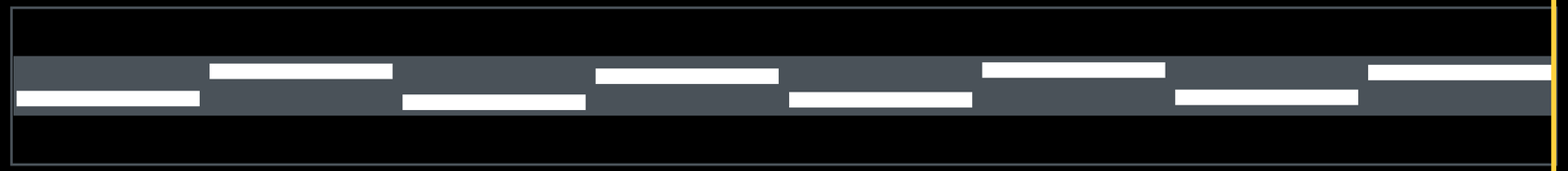

one reading is a guess

# the knob: integration time

few long readings



more, shorter readings



many short readings

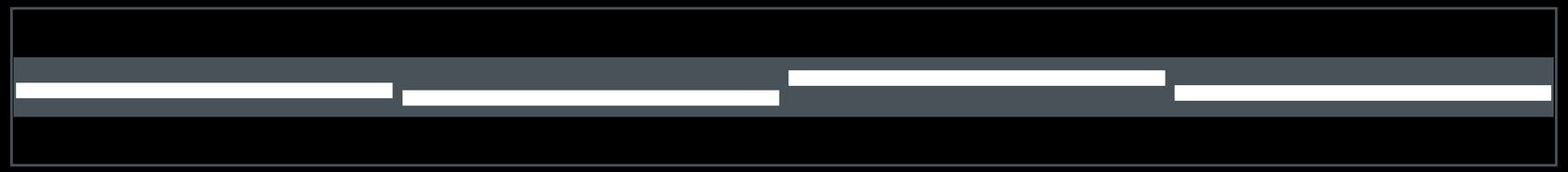




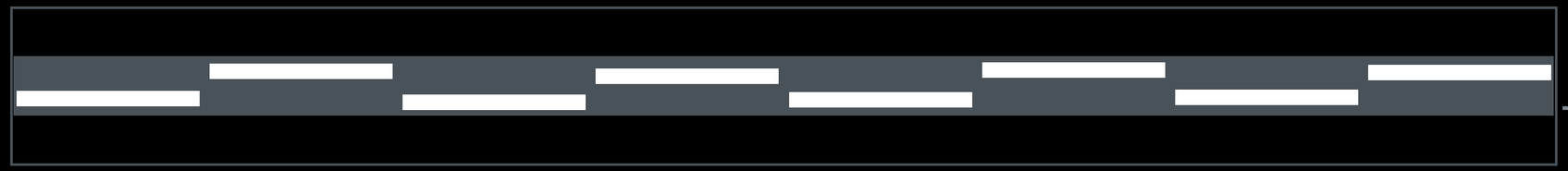
one second

# the knob: integration time

few long readings



more, shorter readings



the band that still reads correctly

many short readings



these land in the wrong colour

one second

# a longer window gives calmer readings, a shorter one gives them faster.

where the best trade-off lies for your setup, only a measurement can tell.

part 4

# build evidence

two teams improve their result

team a

changed distance and integration time

recognition improved

team b

changed only distance

recognition improved

two teams improve their result

team a

changed distance and integration time

recognition improved



what caused it?

team b

changed only distance

recognition improved



`distance`

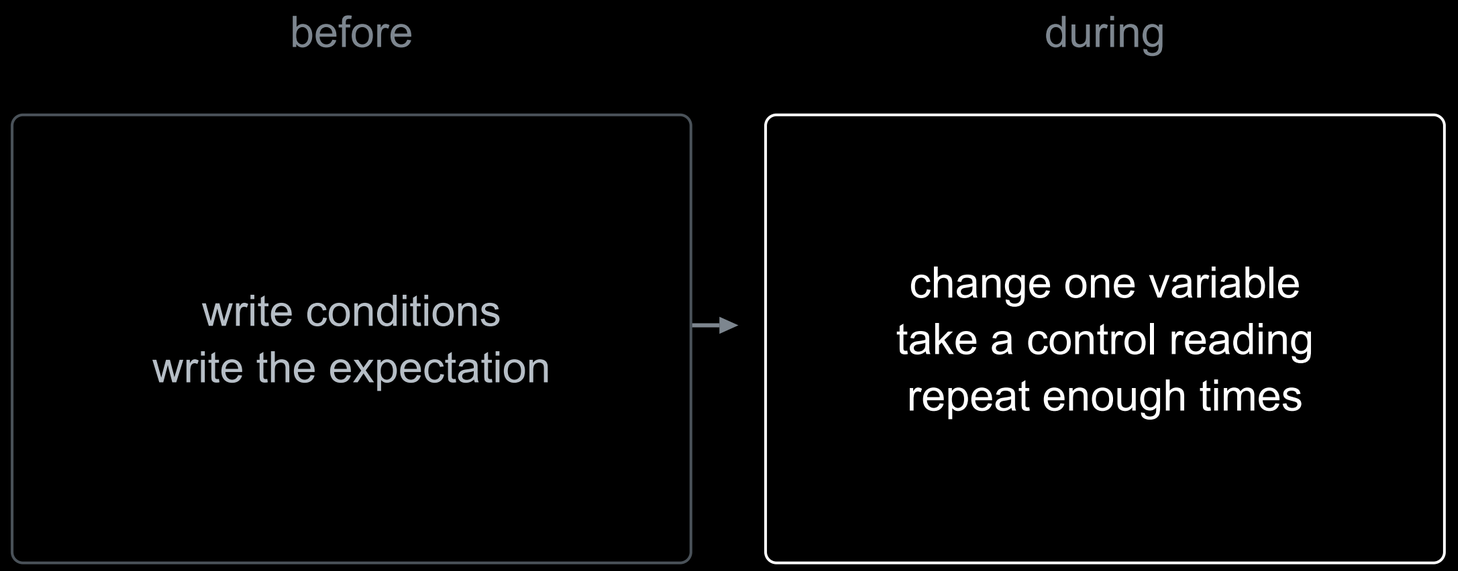
change one variable at a time.

# what makes a measurement series

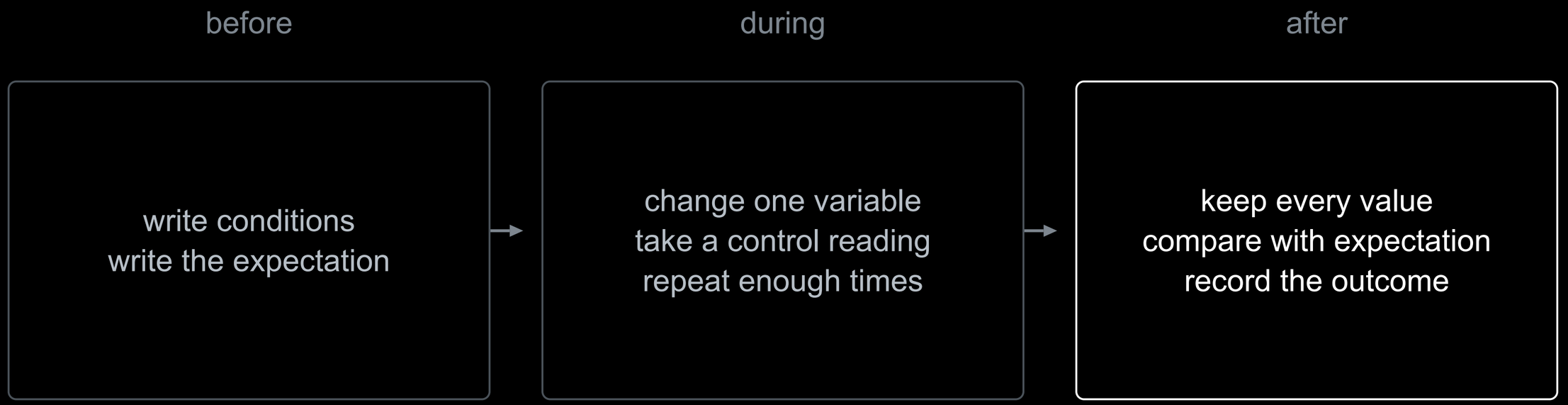
before

write conditions
write the expectation

# what makes a measurement series



## what makes a measurement series




a repeatable result is worth more than an impressive one.

luck or skill?





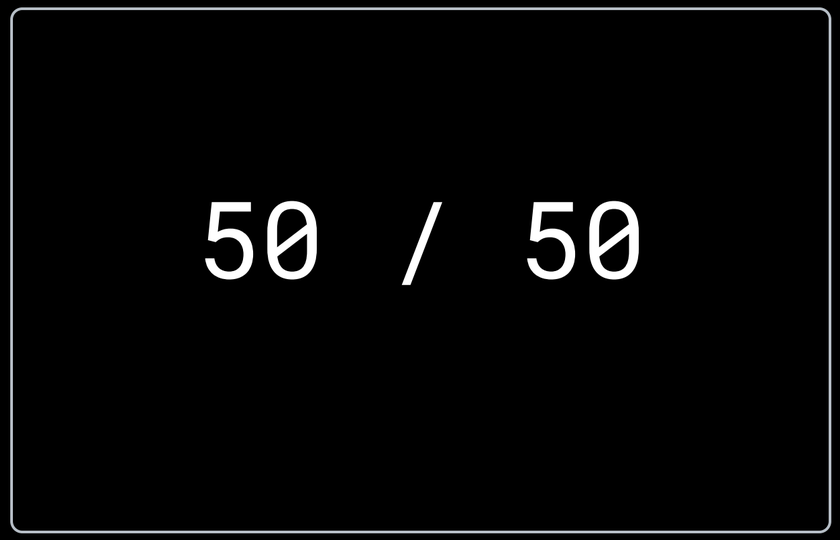


guessing succeeds about once in 32 attempts

luck or skill?



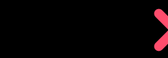

guessing succeeds about once in 32 attempts




`guessing: about 1 in 1,125,899,906,842,624`

luck or skill?

5 / 5



guessing succeeds about once in 32 attempts

50 / 50



`guessing: about 1 in 1,125,899,906,842,624`

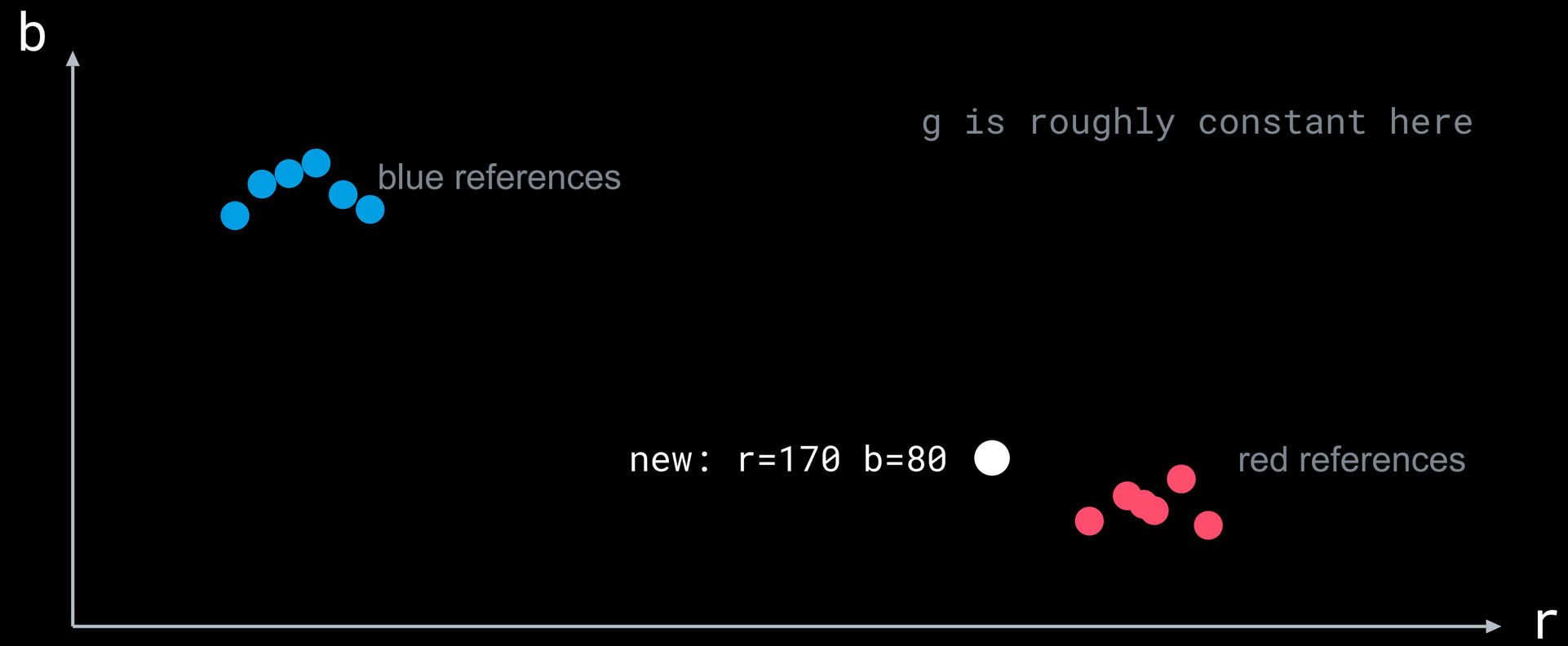
evidence

calibrate, then classify



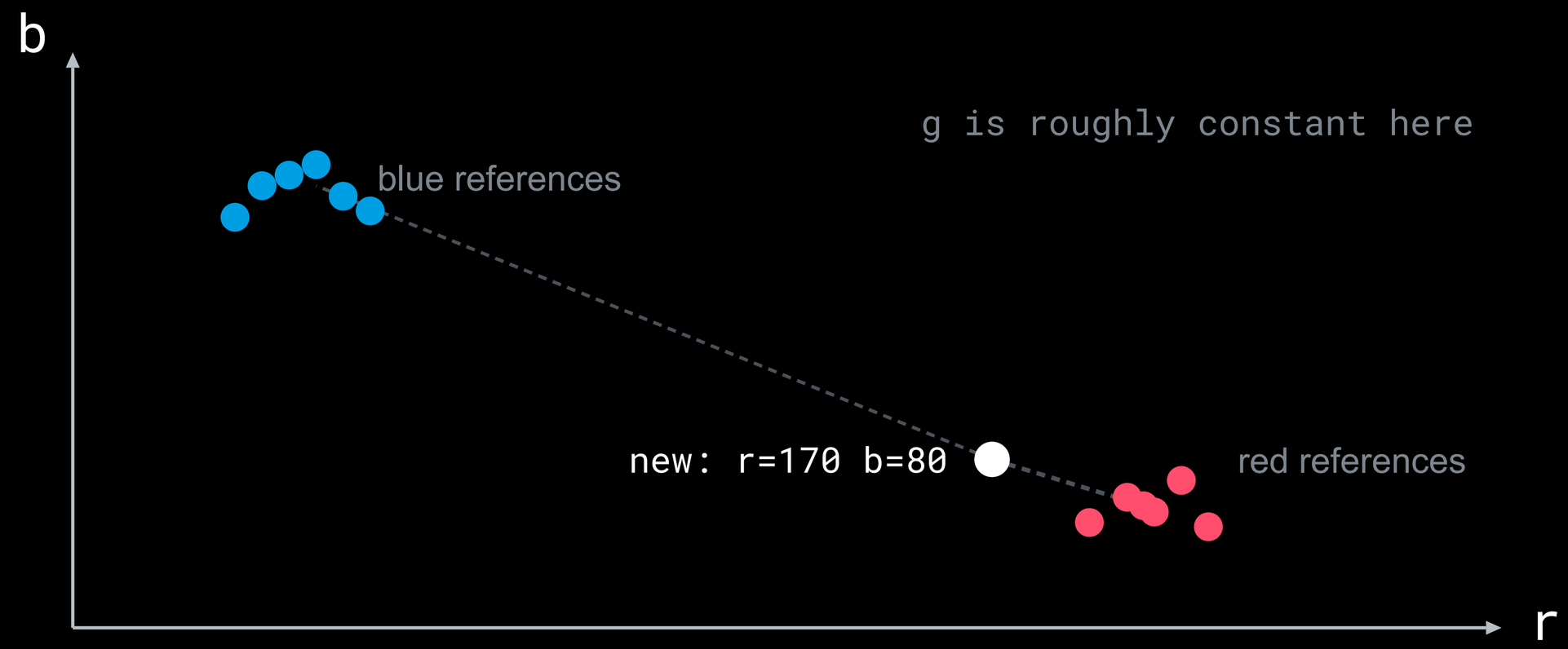

measure known colours many times

calibrate, then classify



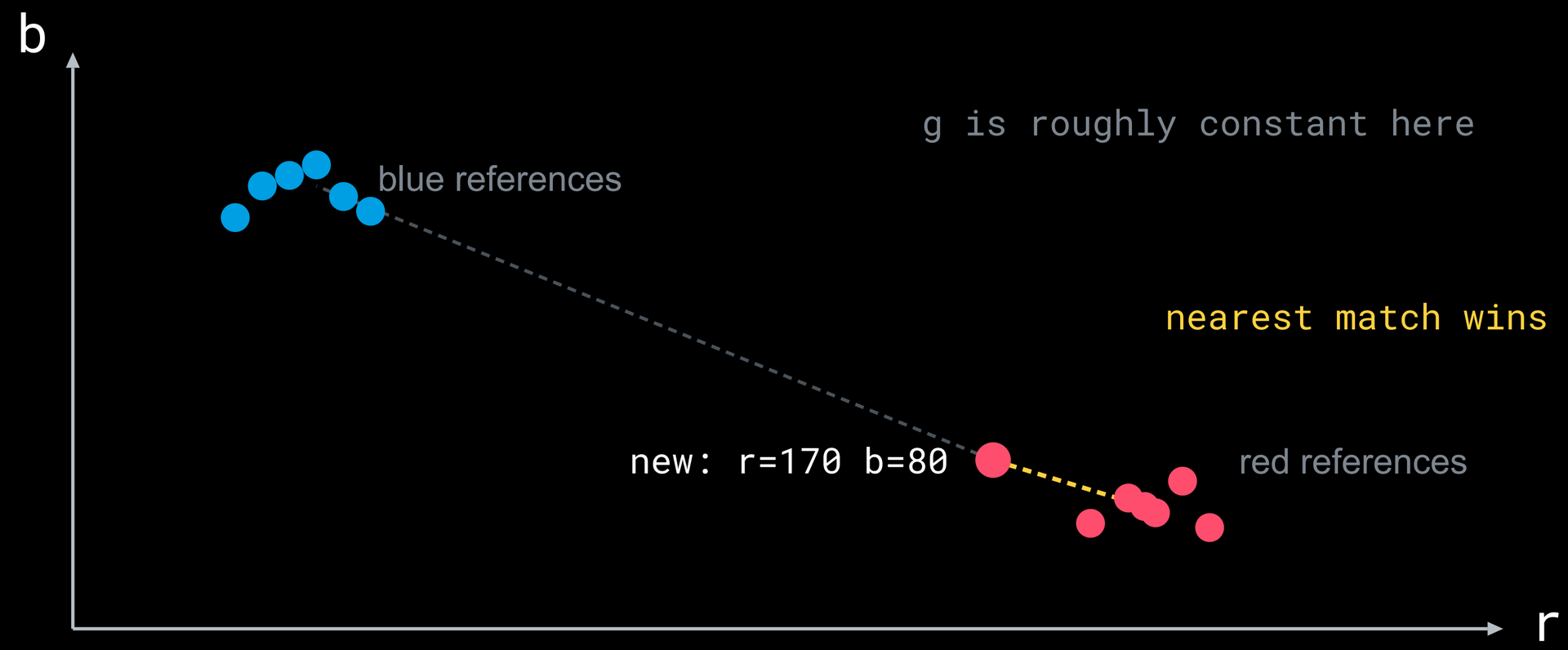

measure known colours many times

calibrate, then classify




measure known colours many times

calibrate, then classify




measure known colours many times

# when the assistant and the data disagree

assistant suggestion

"increase the gain —
recognition will improve"

your measurement series

```
gain ↑
recognition: 94% → 82%
```

# when the assistant and the data disagree

## assistant suggestion

"increase the gain —
recognition will improve"

## your measurement series

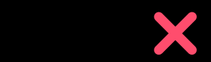
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recognition: 94% → 82%
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✓ one variable ✓ enough repetitions ✓ control reading

# when the assistant and the data disagree

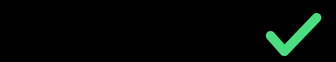
## assistant suggestion

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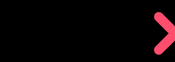
✓ one variable ✓ enough repetitions ✓ control reading

ground truth for your setup

# when the assistant and the data disagree

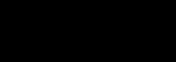
## assistant suggestion

"increase the gain —
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## your measurement series

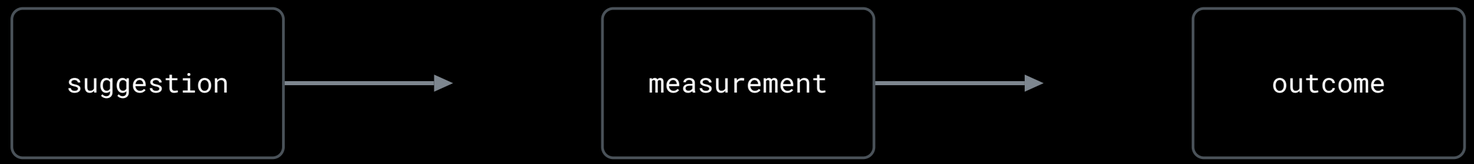
```
gain ↑
recognition: 94% → 82%
```



✓ one variable ✓ enough repetitions ✓ control reading

**ground truth for your setup**

`log of mistakes`



# if you did not measure it, you do not know it.

one reading is not a measurement series.