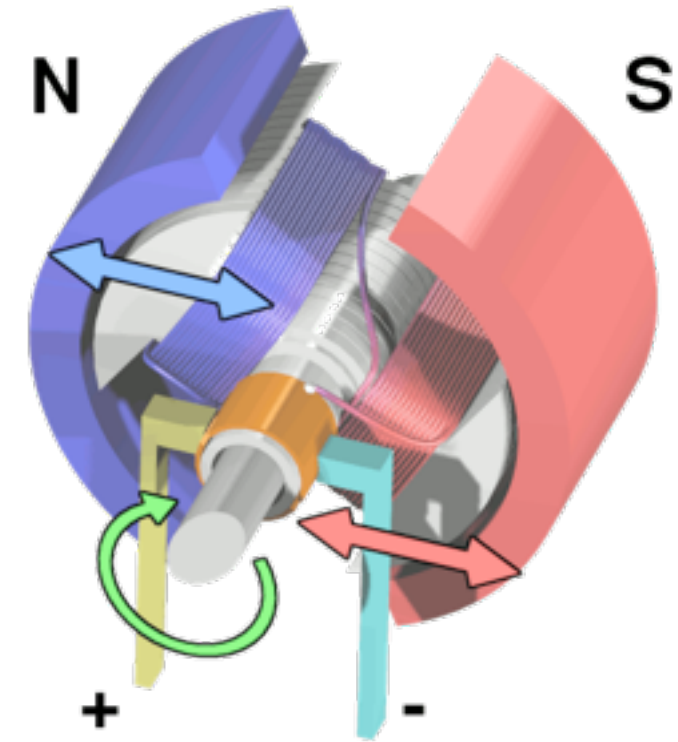
EMAP PHYSICS

P. LeClair
UA Department of Physics & Astronomy

The plan



- What do you need to survive physics? Thrive?
  - math
  - critical thinking / problem solving
  - experiments ...
- What are we going to do?
  - not PH105/106 ...
  - the ‘flavor’ of physics
  - some tools you will need
  - some background as to how we think

How?

- We’ll mostly do experiments.
  - Experiments *similar* to PH105/106
- Hypothesis + reality check ...
  - have an idea, then test it
  - how good was the test?
  - math is the language we use for this

Specifically?

- Each session has one key idea
- This idea is *testable* ... or it is not science
- So we test it.

- How good is our test? How well did it work?
  - a measure of the result & accuracy
  - does it make any sense? predict something else ...

Example

- Your reaction time is better than mine ...
- Every time? By how much?
- What is the variability?
- How good is the measurement anyway?

Schedule

Session	Lab	Math-related things
Tues 7 July 3:45-5:45	intro / Error analysis	uncertainty, basic statistics (mean, std. dev)
Fri 10 July 3:45-5:45	Coefficient of restitution	sequence & series, logarithms, power laws
Tues 14 July 4-6	Atomic spectroscopy	trigonometry
Thu 16 July 1:30-3:30	dc circuits	linear relationships
Tue 21 July 3:45-5:45	resistive circuits (resistor networks)	systems of linear equations
Wed 22 July 1:30-3:30	Planck's constant determination	trigonometry, exponential behavior, linear regression
Tue 28 July 1:30-3:30	RC circuits	exponential behavior, non-linear regression, logarithms
Fri 31 July 1:30-3:30	mutual inductance / wireless power	linearization, rate of change, trig functions
Mon 3 Aug 1:30-3:30	homopolar motors	vector relationships (cross product)
Wed 5 Aug 1:30-3:30	remote controls	time-dependent behavior, trig functions, 3D geometry in spherical coordinates

http://faculty.mint.ua.edu/~pleclair/EMAP_09/

Format

Quick (10-20min) intro to the idea / experiment

Do the experiment!
  groups of 5 or so

Analyze the data
  was the idea right? put numbers on that ...

Repeat if necessary

What would you do next?

Follow-up ... homework!

So: let’s get at it!

- Today: gauging reaction time
- one measurement vs. many
- how does accuracy improve?
- how to measure accuracy?
- care & feeding of data ...

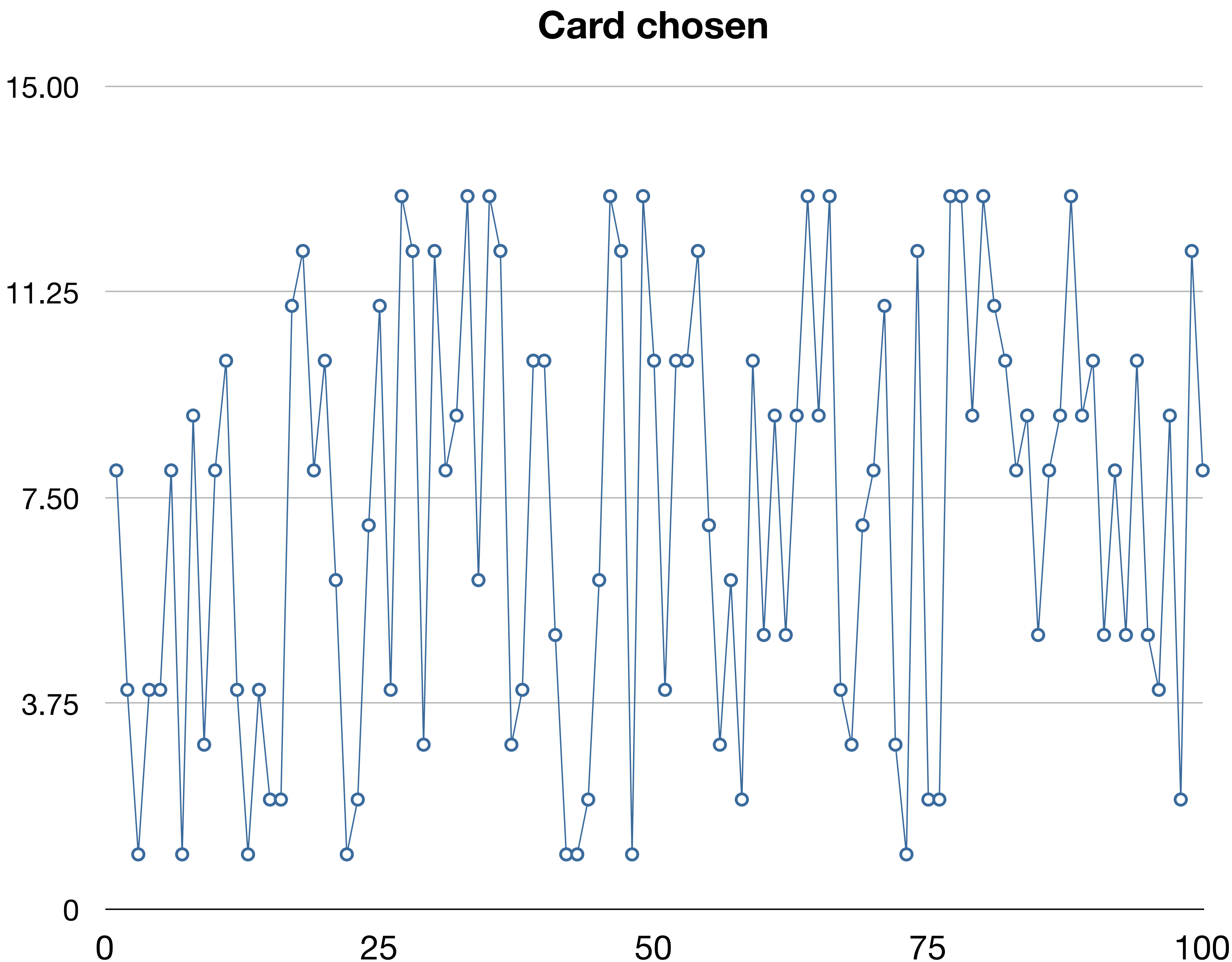
Homework for next time

- Bring in a small rubber ball of some kind
- Which sort bounces the ‘best’
- What do we mean by ‘best’

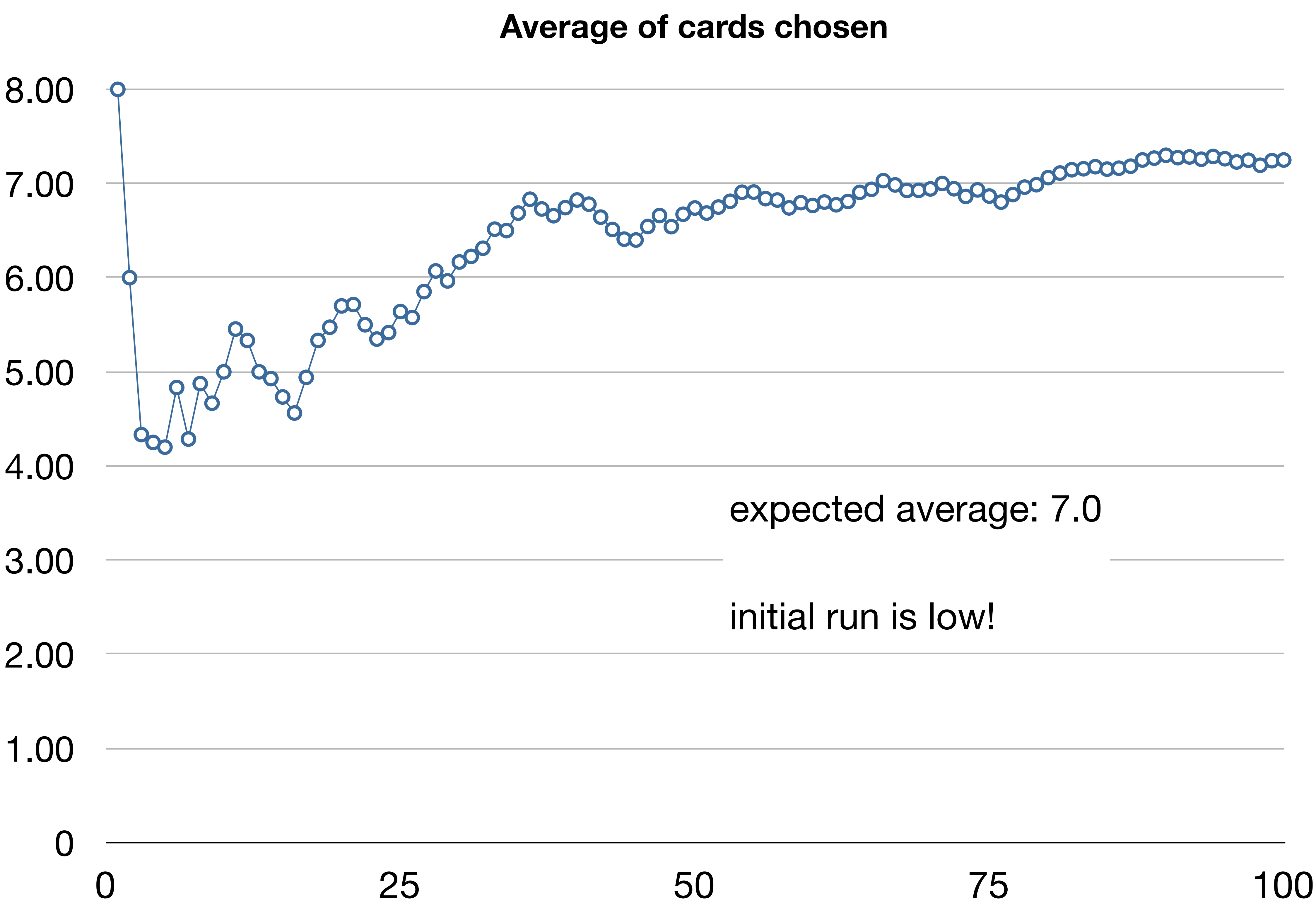
My experiment: picking cards

- give each one a number
- Ace = 1, 2 = 2 ... Jack = 11 ... King = 13
- what is the average card?
  - we expect it must be 7 ...
- what is the spread? how to define this?

100 trials ...

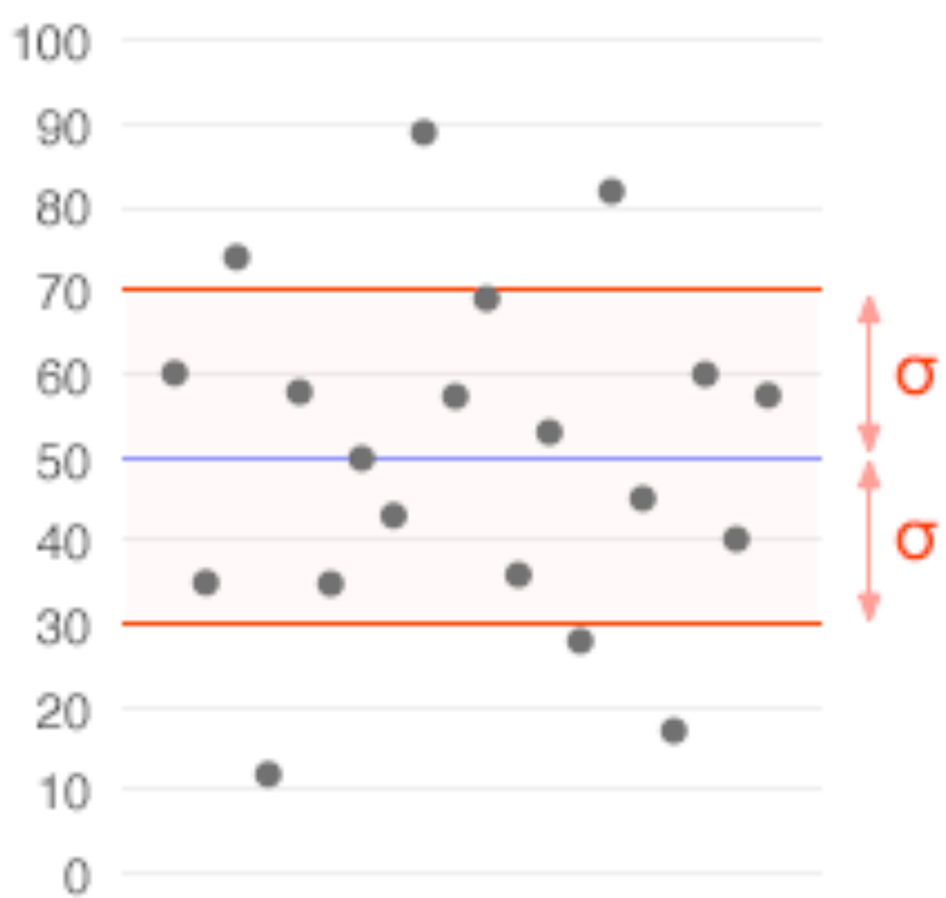


equal number of each
average must be 7, if one chooses enough cards
takes ~50 before 'luck' is moot!

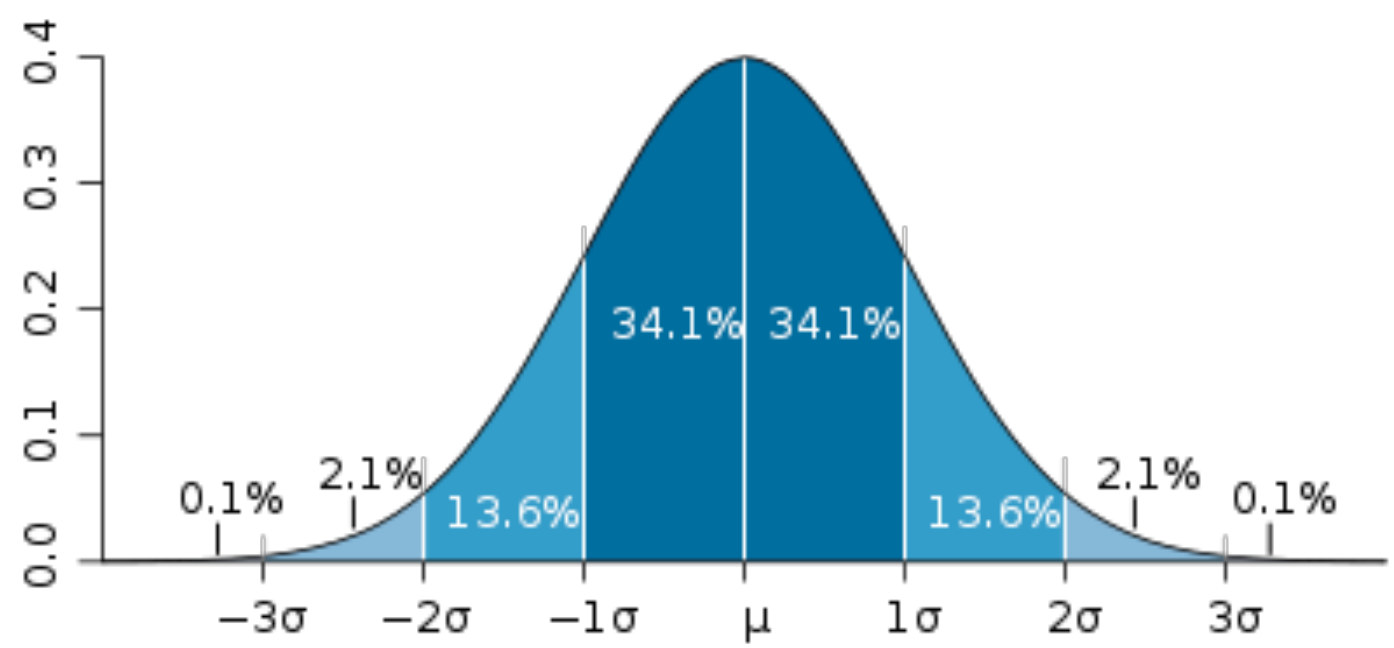


standard deviation is a measure of the variability dispersion in a population or data set

low standard deviation: data tends to lie close to the average (mean)
high standard deviation: data spread over a large range



data set: data clustered about average



many trials: follow a *distribution*

~68% within +/- 1 standard deviation
~95% within +/- 2 standard deviations
~99.7% within +/- 3 ...

so what?

- knowing the standard deviation tells you
  - if subsequent measurements are outliers
  - what to expect next
  - *accuracy* of a set of data
  - variability in a large batch
- “six sigma” - quality control
  - means one out of 500 million!

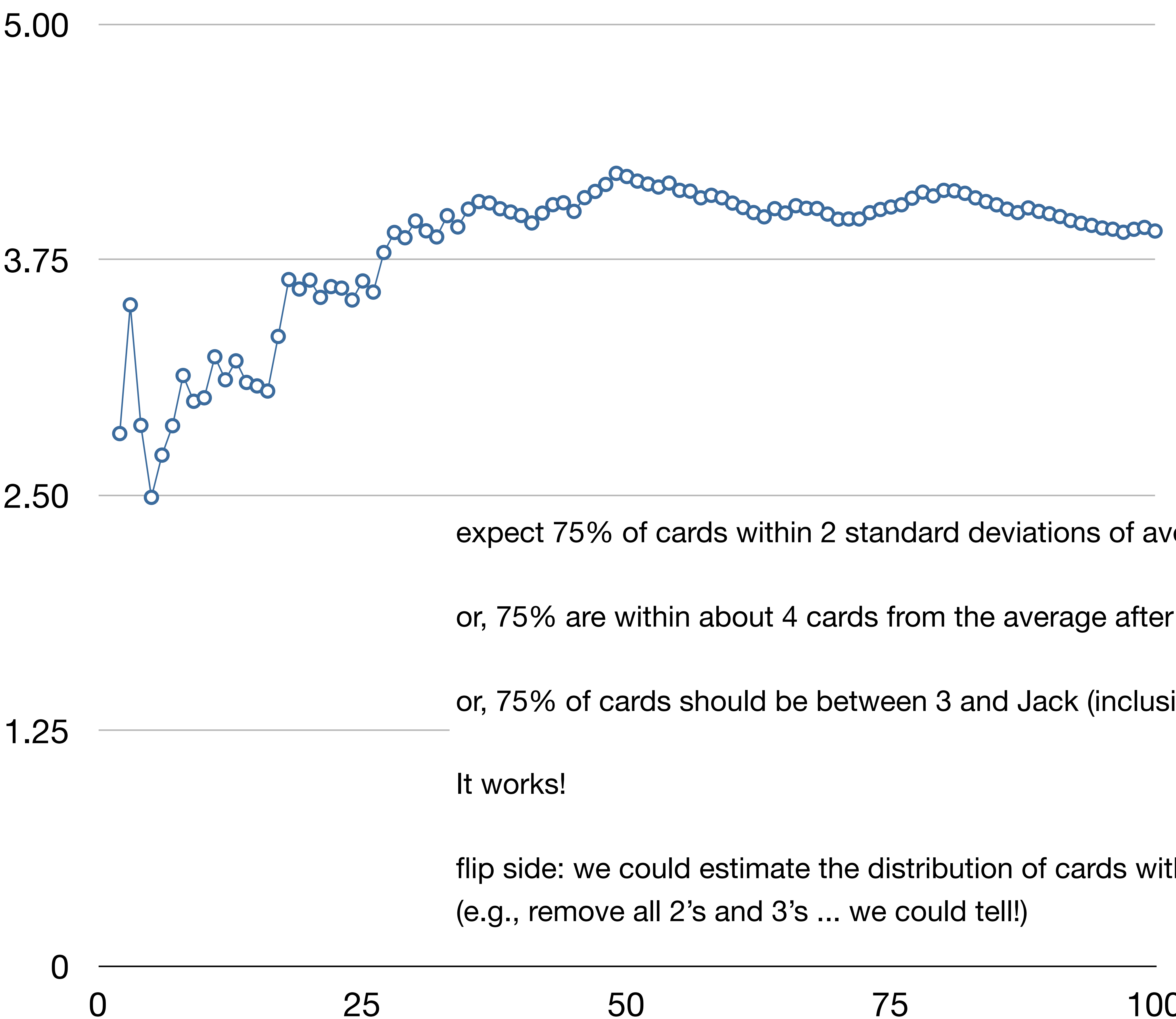
so what?

if the mean of the measurements is too far away from the prediction, then the theory being tested probably needs to be revised!

particle physics: 3-sigma standard typical

more than that ... probably a new effect!

Standard deviation



expect 75% of cards within 2 standard deviations of average

or, 75% are within about 4 cards from the average after 100 trials

or, 75% of cards should be between 3 and Jack (inclusive)

It works!

flip side: we could estimate the distribution of cards without prior knowledge
(e.g., remove all 2’s and 3’s ... we could tell!)

now you try ...

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

$$\sigma = \frac{1}{n}\sqrt{n\left(\sum_{i=1}^{n} x_i^2\right) - \left(\sum_{i=1}^{n} x_i\right)^2}$$

say your data is 11.0, 11.5, 12.0

$$\overline{x}_3 = \frac{1}{n}\sum_{i}^{n} x_i = \frac{1}{3}\left[11.0 + 11.5 + 12.0\right] = 11.5$$

$$\sigma_3 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2} = \sqrt{\frac{1}{3}}\sqrt{(11.0 - 11.5)^2 + (11.5 - 11.5)^2 + (12.0 - 11.5)^2)} \approx 0.41$$

$$\sigma_3 = \frac{1}{3}\sqrt{3 \cdot (11.0^2 + 11.5^2 + 12.0^2) - (11.0 + 11.5 + 12.0)^2} \approx 0.41$$

point **point** i	**distance** x_i	**running** **average** $\overline{x}$	**running** σ
1	28.1	28.1	–
2	28.5	28.3	0.20
3	28.7	28.4	0.25
4	28.3	…	…
5	28.0	…	…
…	…	…	…