Designing an Experiment (in 2 parts)

13

Probability and Statistics

COMS10011

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Part 1

let’s do an experiment!

memorization game

group 1

memorize as much
as you can

group 2

if you beat group 1 =
chocolate!

take a piece of paper and a pen

I will tell a list of numbers

“1,2,3,6,write”

only when “write” -> write the list on paper

I will show the list

1, 2, 3, 6

if you are **correct** continue the game

if you wrong stop the game, remember *best score* practice trials

1, 4, 9 (size=3)

practice trials

8, 7, 3, 5, 6, 1 ,2 (size=7)

let’s start the real experiment!

trial

3, 2, 8 (size=3)

trial

4, 2, 5, 1 (size=4)

trial

7, 2, 5, 3, 1 (size=5)

trial

6, 2, 9, 8, 5, 1 (size=6)

trial

7, 4, 1, 8, 6, 3, 2 (size=7)

trial

2, 7, 4, 9, 3, 1, 5, 9 (size=8)

trial

1, 6, 7, 8, 5, 3, 1, 4, 6 (size=9)

trial

6, 4, 1, 9, 3, 8, 2, 1, 7, 9 (size=10)

trial

2, 7, 4, 1, 5, 7, 3, 8, 6, 4, 7 (size=11) what is your best score (size of the list)?

enter it at

https://tinyurl.com/COMS10011

let's first
look at the results

1 research question / hypothesis?

2 in(dependant) variables?

3a within or between subjects?

3b counterbalancing?

4 how many repetitions/trials?

5 look at raw data

6 look at distributions

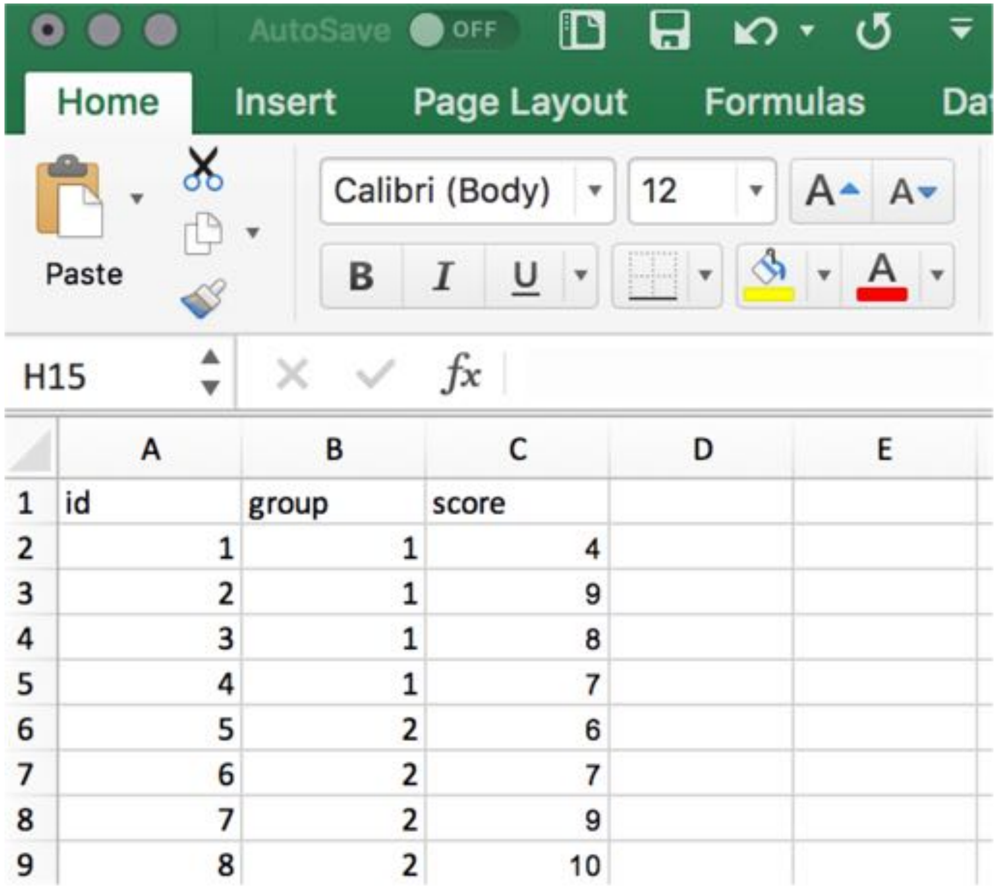
7a check for normality

7b run some stats

8 conclude

look at raw data

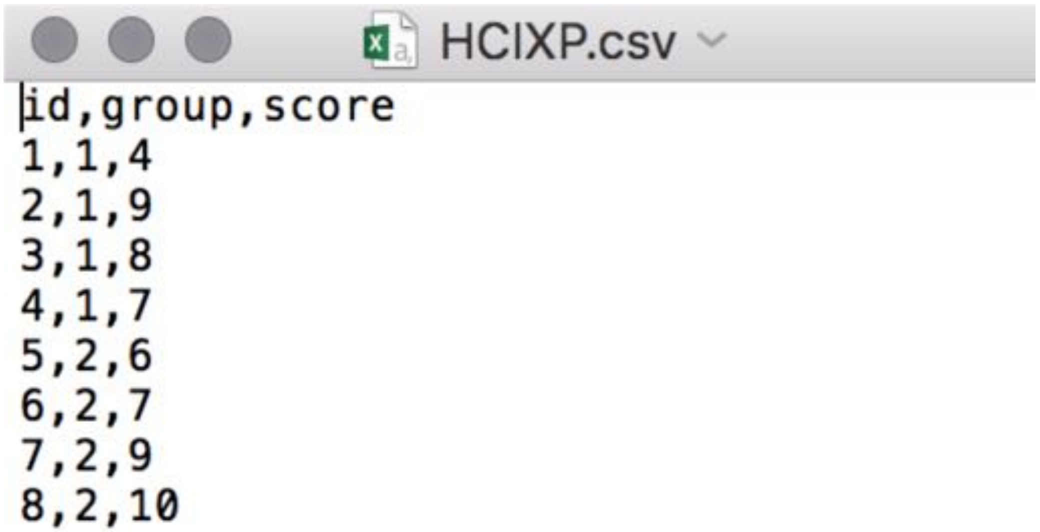
let's put everything in a table (excel is great for that)



	A	B	C	D	E
1	id	group	score		
2	1	1	4		
3	2	1	9		
4	3	1	8		
5	4	1	7		
6	5	2	6		
7	6	2	7		
8	7	2	9		
9	8	2	10		

save your file as a .csv (comma separated virgule is a format to store tables as text files)

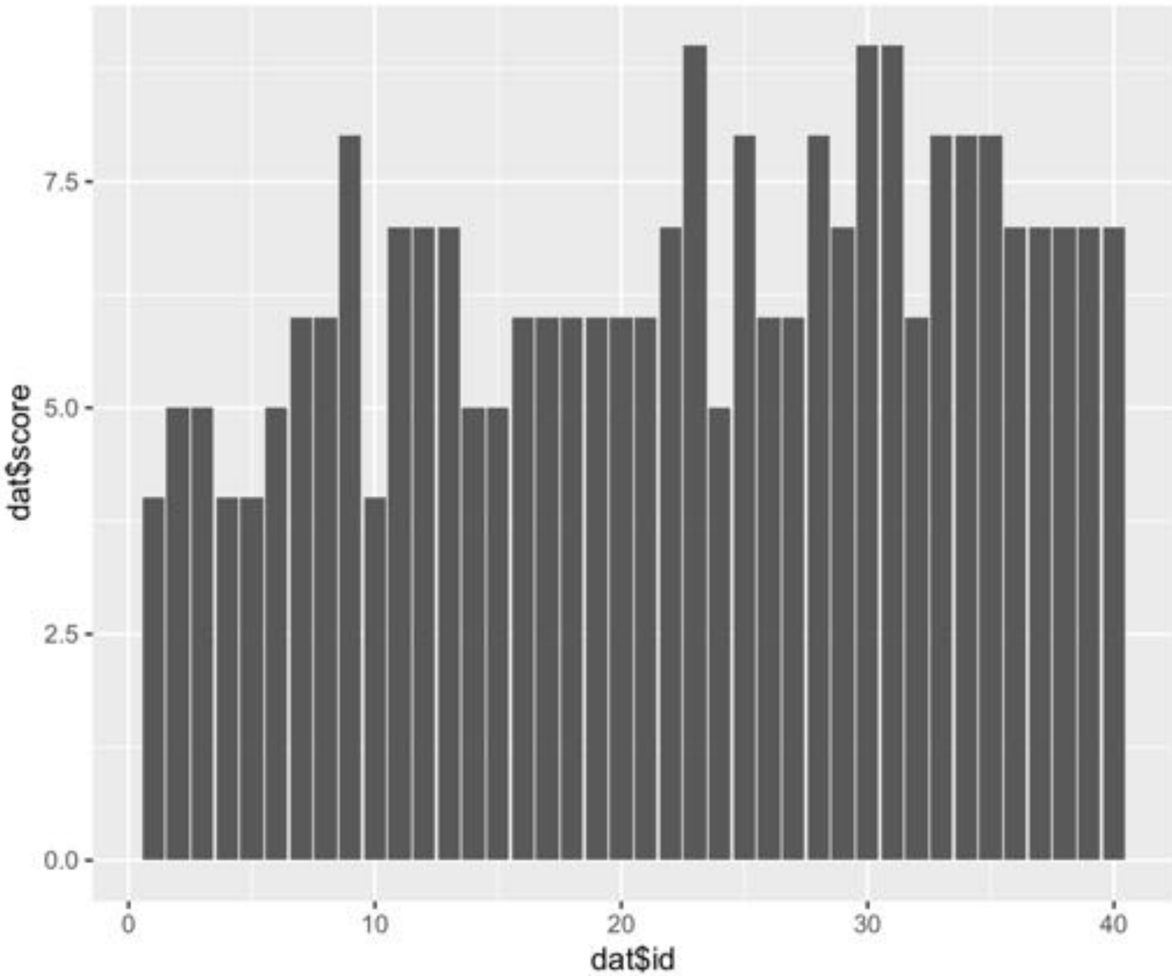
you can open csv with excel, text file an many other software




```
id,group,score
1,1,4
2,1,9
3,1,8
4,1,7
5,2,6
6,2,7
7,2,9
8,2,10
```

```
dat = read.csv("HCIXP.csv", header = TRUE)
print(dat) # look at the file in R
```

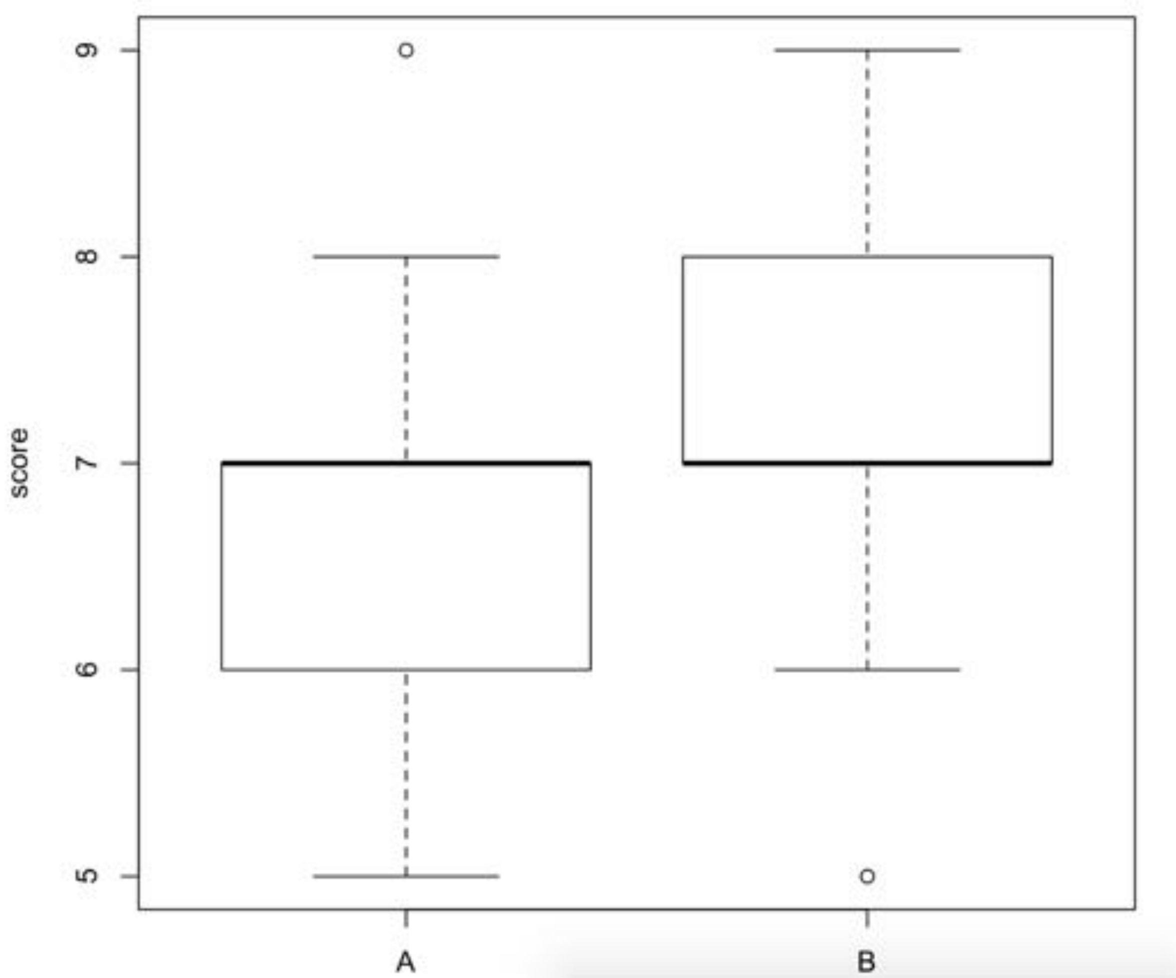
```
dat = read.csv("HCIXP.csv", header = TRUE)
print(dat) # look at the file in R

library(ggplot2)

ggplot(dat, aes(x = dat$id, y = dat$score)) +
geom_bar(stat = 'identity', position = 'dodge')
```



first: does the data look ok?

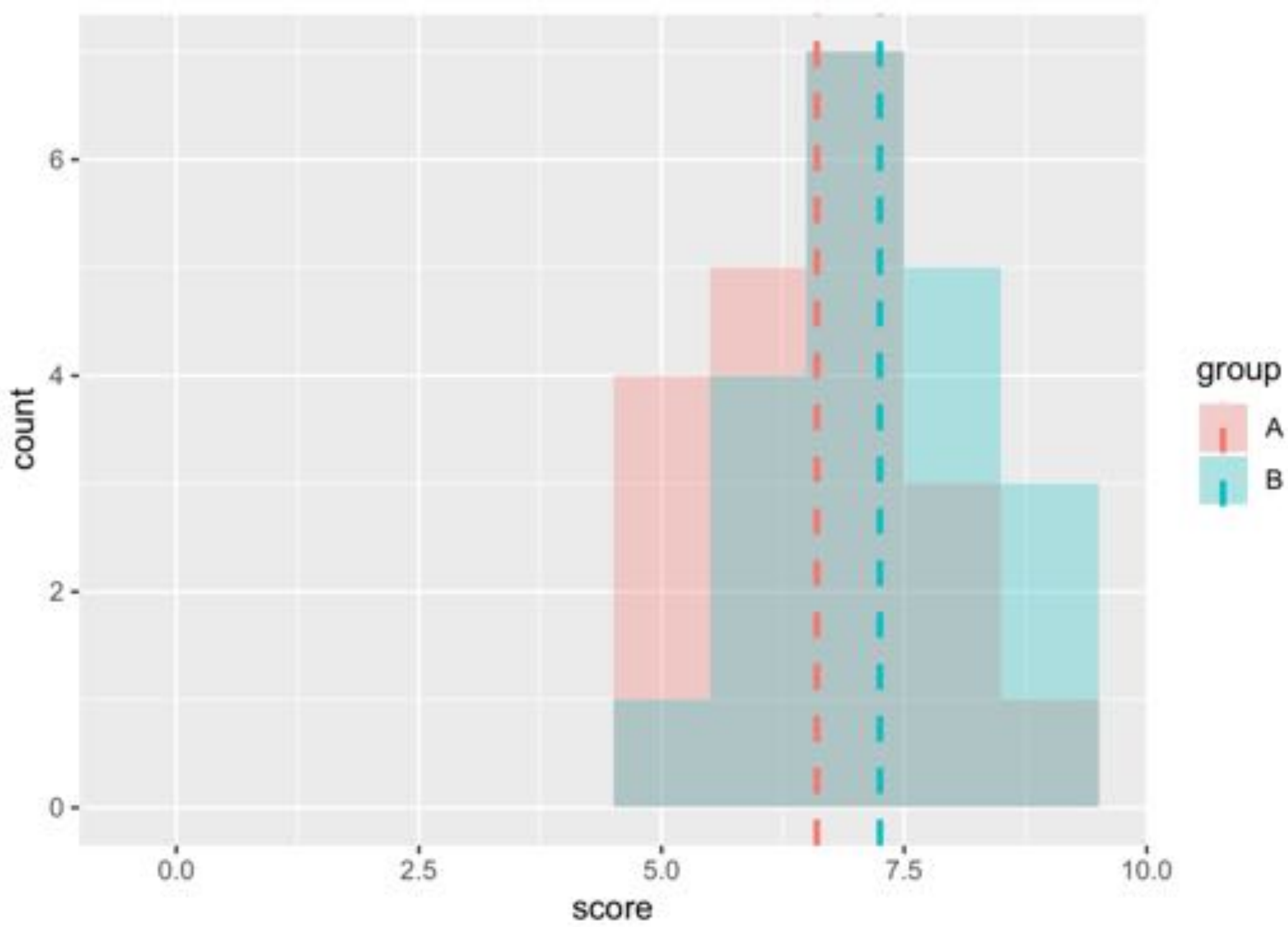
search for bugs, fatigue effect, learning effect or outliers (>3 times std) = remove / redo xp

```
plot(score ~ group, data = dat)
```



look at histograms

```
# Find the mean of each group
library(plyr)
cdat <- ddply(dat, "group", summarise,
score.mean=mean(score))
cdat

  group score.mean
1     A    5.60
2     B    7.25

# Overlaid histograms with means
ggplot(dat, aes(x=score, fill=group)) +
geom_histogram(binwidth=1, alpha=.3, position="identity")
+ geom_vline(data=cdat, aes(xintercept=score.mean,
colour=group), linetype="dashed", size=1) +
expand_limits(x = 0, y = 0)
```



your gut feeling: are these groups different?

are these distributions likely to have happen by chance?

… is this the results of the factor (chocolate)?

use a statistic test

```
# Use a t-test (two-tails, unpaired)
t.test(dat$score[dat$group == "A"], dat$score[dat$group
=="B"], alternative = "two.sided")

      Welch Two Sample t-test

      data:  dat$score[dat$group == "A"] and
      dat$score[dat$group == "B"]
      t = -1.8185, df = 37.982, p-value = 0.07688
      alternative hypothesis: true difference in means is
      not equal to 0
      95 percent confidence interval:-
      1.37361001  0.07361001
      sample estimates: mean of x mean of
      y  6.60      7.25
```

"We could not find any significance differences!"

p-value = 0.07

is is enough to say that the two groups are different?

-> nope, not under significant level of 0.05

can we say that the two groups are same then?

-> nope, can only prove things are different, but not that they are the same

8

conclude

if p was lower than significance level we could say:

"a student t-test showed significant difference between the two group (two-tailed $t(46)=4.520$, $p < 0.005$)"

otherwise:

"we did not find any significant results"

cannot conclude, no evidences to show that having chocolate rewards improve memorisation

let’s go
backward a little

1. research question / hypothesis?
2. in(dependant) variables?
3. a. within or between subjects?
   b. counterbalancing?
4. how many repetitions/trials?
5. look at raw data
6. look at distributions
7. a. check for normality
   b. run some stats
8. conclude

1

research question::

a statement that identifies a phenomenon to be studied

in our xp: I believe that **rewards improve memorization skills**

… suggested by <*insert smart guess*>

hypotheses::

statement of the predicted relationship between at least two experimental variables

provisional answer to a research question

in our xp: **group chocolate will have a higher memorisation score than group with no reward**

(in)dependent variable ::

the **dependent variable** is the event studied and expected to change whenever the **independent variable** is altered

vary A → make A
an **independent variable**

so we want to show that **A causes B**

measure B → make B
a **dependent variable**

in our xp?

independent variable = group type (nothing vs. chocolate)

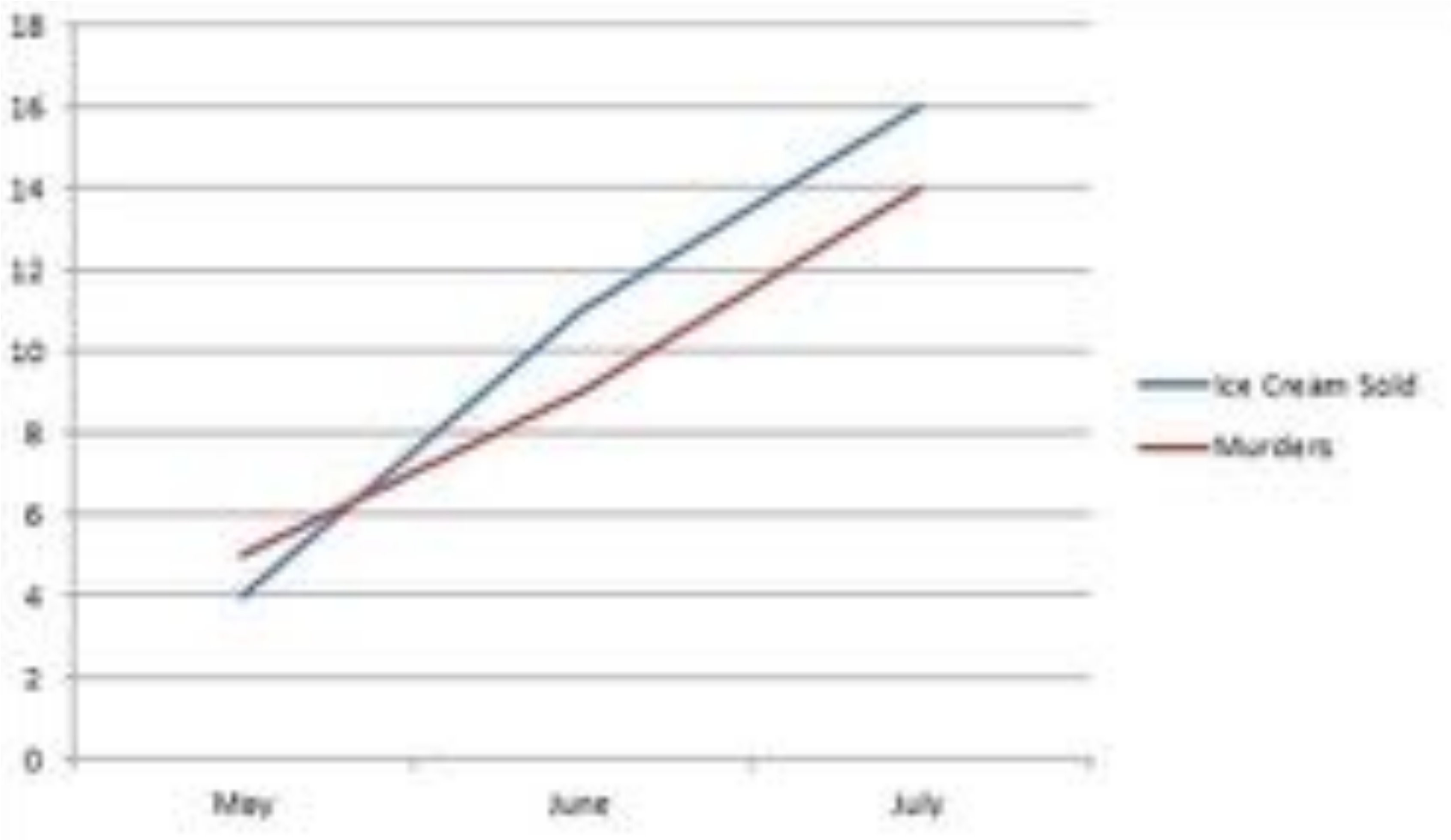
dependent variable = memorization score everything else should be a…

controlled variable ::

the variables that are kept constant to prevent their influence on the effect of the independent variable on the dependent avoid…

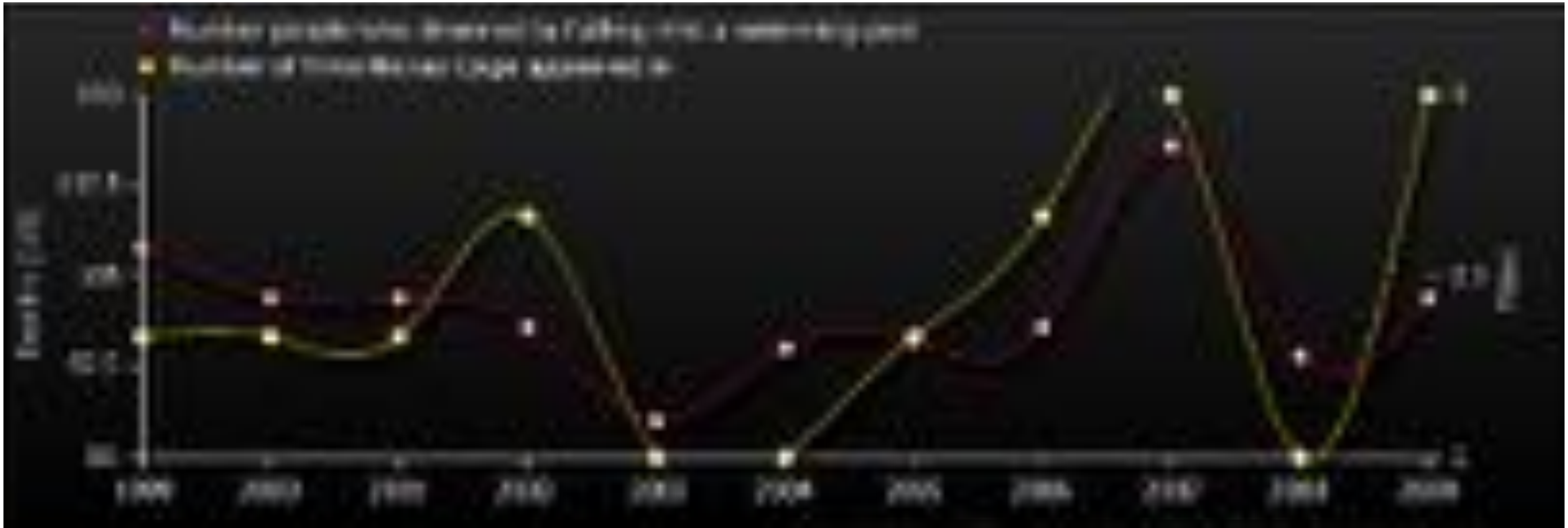
confounding variable ::

extraneous variables that **correlates with both** the dependent variable and the independent variable



ice cream consumption leads to murder

counfounding : weather temperature



number of people drowned by falling into a swimming-pool correlates with number of films Nicolas Cage appeared in this is not about **correlation**

this is about how to show **causality,**
i.e., that **some A causes some B**

in our xp, do we have confounding variables?

yes, it is not greatly designed :s

gender, age, background, what you ate before, if you like chocolate or not, if you are competitive and want the others not to have chocolate, if some of the numbers are familiar to you etc.

what can we do about it?

- avoid them by controlling as much as you can in the environment
- if you cannot, make it an independent variable (e.g. gender)
- some are inherent *noise* (human individuality), use more participants to get *statistical power*

the goal of a quantitative study is to find
a signal in **a lot of noise**

experimental design:

aims at maximizing your chances of **finding the signal** and not the noise

1. need to absolutely **avoid systematic biases**

(e.g., learning effect, fatigue). They give you **false results!**

2. **avoid random noise.** It makes your results non-significant. Clever experimental design is all about keeping the noise down

e.g. in our xp, I made you **practice before**!

within vs. between?

within = all participants do same

between = participants do only certain conditions suffer less user variation

statistical power with less participants

no biases from other conditions (e.g. transfer of learning)

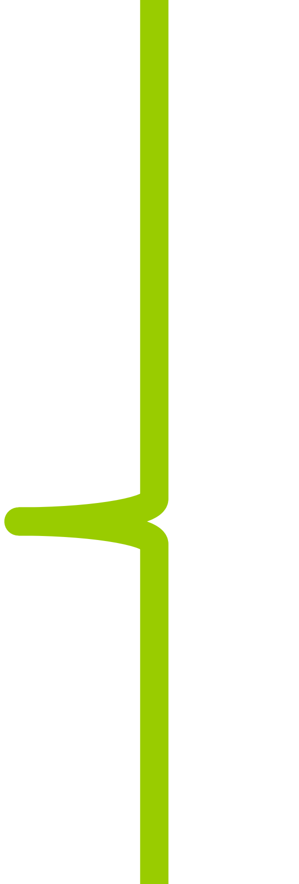
within vs. between?

within = all participants do same

between = participants do only certain conditions

in our xp, it had to be **between subjects**
(because of the rewards)

participants did not do all conditions:
½ did the control condition
½ the reward condition



imagine a **within subjects** (test how fast we click an icon):

participants do all conditions:
they start with the trackpad
when finished they do the mouse

is it a good idea?
nope -> learning effect

counterbalancing ::

a method of avoiding confounding among variables

presenting conditions in a different order

one approach to counterbalancing is to use a…

A	B	C
C	A	B
B	C	A

Latin square ::

an $n \times n$ array filled with n different Latin letters, each occurring exactly once in each row and exactly once in each column.

how many trials?

ideally make as much trials as you can to reduce noise but try to keep experiment around 30 min … max 40 min in our xp, we did only one trial because of time constraint, but should have done more to **reduce noises**

summary

1 research question / hypothesis?

2 in(dependant) variables?

3a within or between subjects?

3b counterbalancing?

4 how many repetitions/trials?

5 look at raw data

6 look at distributions

7a check for normality

we will see why

7b run some stats

so far we know t-test

8 conclude

end of part one

1 research question / hypothesis?

2 in(dependant) variables?

3a within or between subjects?

3b counterbalancing?

4 how many repetitions/trials?

5 look at raw data

6 look at distributions

7a we will see why
check for normality

7b run some stats
so far we know t-test

8 conclude

Part 2

let’s
complexify a little

in our xp, let’s add a 3rd imaginary group

they get a slap if they had the smallest memorisation score
(obviously not ethical so let’s keep this hypothetical!)

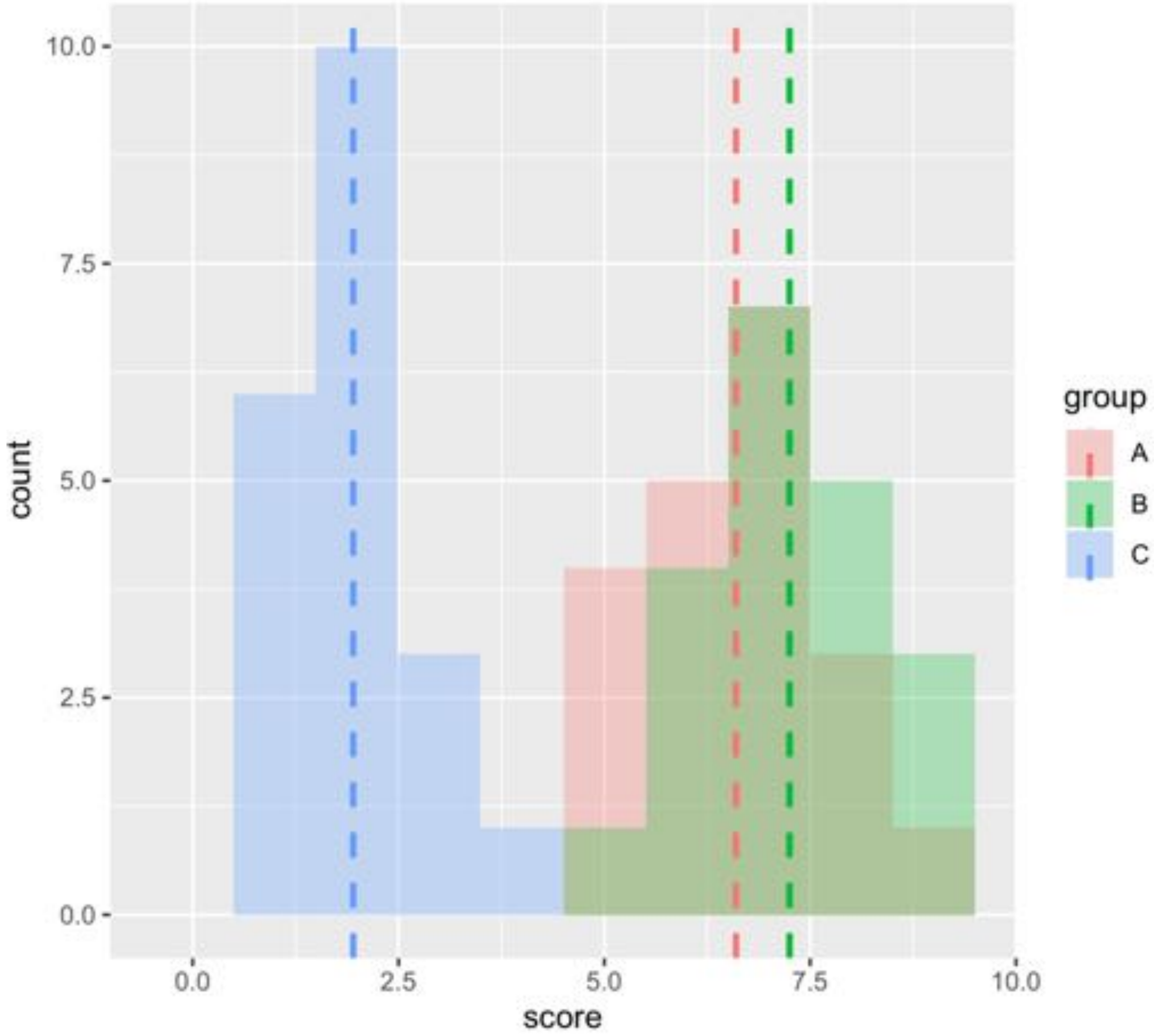
E57

Group C: “slap”

	A	B	C	D
15	14	A	6	
16	15	A	6	
17	16	A	7	
18	17	A	7	
19	18	A	7	
20	19	A	7	
21	20	A	7	
22	21	B	6	
23	22	B	7	
24	23	B	9	
25	24	B	5	
26	25	B	8	
27	26	B	6	
28	27	B	6	
29	28	B	8	
30	29	B	7	
31	30	B	9	
32	31	B	9	
33	32	B	6	
34	33	B	8	
35	34	B	8	
36	35	B	8	
37	36	B	7	
38	37	B	7	
39	38	B	7	
40	39	B	7	
41	40	B	7	
42	41	C	1	
43	42	C	2	
44	43	C	1	
45	44	C	2	
46	45	C	1	
47	46	C	2	
48	47	C	3	
49	48	C	2	
50	49	C	2	
51	50	C	1	
52	51	C	1	
53	52	C	4	
54	53	C	2	
55	54	C	2	
56	55	C	2	

I made up some data

```
# Find the mean of each group
dat = read.csv("HCIXP-anova.csv", header = TRUE)
cdat <- ddply(dat, "group", summarise,
score.mean=mean(score))
cdat

  group score.mean
1     A       6.60
2     B       7.25
3     C       1.95

# Overlaid histograms with means
ggplot(dat, aes(x=score, fill=group)) +
geom_histogram(binwidth=1, alpha=.3, position="identity")
+ geom_vline(data=cdat, aes(xintercept=score.mean,
colour=group), linetype="dashed", size=1) +
expand_limits(x = 0, y = 0)
```



your gut feeling: are these groups different?

are these distributions likely to have happen by chance?

can we use t-tests?

(3 tests to compare group 1 with 2, 2 with 3 and 1 with 3)

-> yes but use Bonferoni correction

significance level not 0.05 anymore but 0.05 / number of comparisons performed (here 3) so <u>0.016</u>

```
# Use a t-test (two-tails, unpaired)

# (we already know A vs B not significative) so we need to
do

t.test(dat$score[dat$group == "A"], dat$score[dat$group ==
"C"], alternative = "two.sided")

      t = 14.753, df = 34.591, p-value < 2.2e-16

# and

t.test(dat$score[dat$group == "B"], dat$score[dat$group ==
"C"], alternative = "two.sided")

       t = 17.054, df = 34.971, p-value < 2.2e-16
```

In both case p_value < 0.016 so we can conclude!

Another test we can use when we have more than two groups to compare is an ANOVA

we have 3 different conditions (or 1 factor with 3 different levels) so we will do a one-way ANOVA

anova::

analyze of variance to compare multiple variables

one-way anova = one variable with multiple levels

two-way anova = two variables with multiple levels

```
# first we run the one-way anova
library(ez)
ezANOVA(dat,id,between=group,dv=score)
```

```
  Effect DFn DFd        F            p p<.05       ges
1  group   2  57 154.8886 9.056612e-24     * 0.8445923
```

ok something is going to be interesting here

```
# second, run the pairwise comparison

pairwise.t.test(dat$score,dat$group, paired=FALSE,
p.adjust.method="bonferroni")
```

```
  A      B
B 0.16   -
C <2e-16 <2e-16
```

here are significant differences

and we don’t need to do the Bonferroni correction (already included) we can write:

“A one-way ANOVA showed a significant effect on time for the variable Group ($F2,57=154.88$, $p < 0.05$).”

and then:

“Post-hoc comparison t-tests (using Bonferoni correction) showed significant difference between the group C and the group A ($p<0.05$) and between group C and group B ($p<0.05$).”

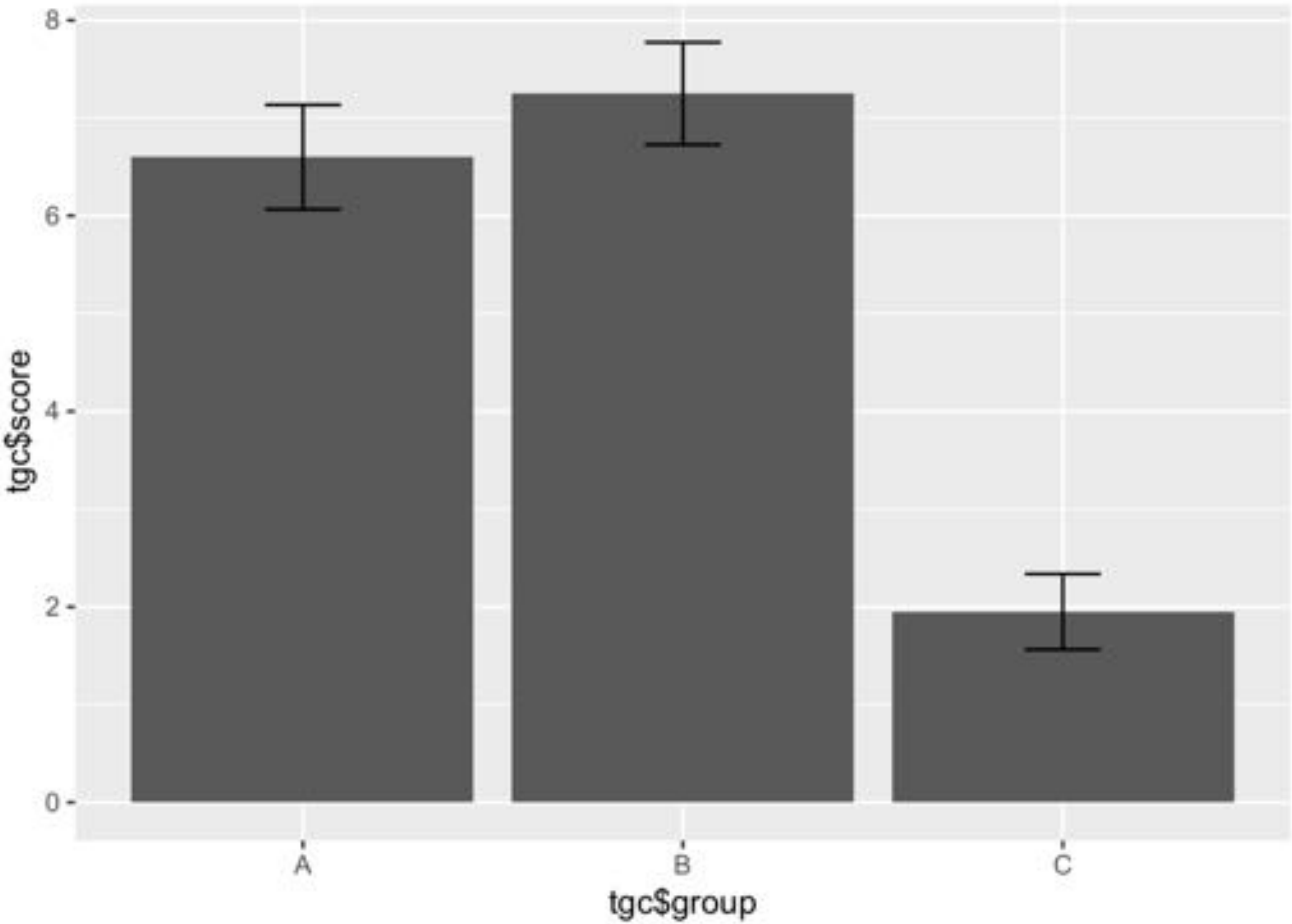
<you could also give means values to give more info>

one last thing you could find useful: how to make a graph with confident interval

```
# first we run the one-way anova
library(Rmisc)
tgc <- summarySE(dat, measurevar="score",
groupvars=c("group"))
tgc
```

```
  group  N score        sd        se        ci
1     A 20  6.60 1.1424811 0.2554665 0.5346976
2     B 20  7.25 1.1180340 0.2500000 0.5232560
3     C 20  1.95 0.8255779 0.1846048 0.3863824
```

```
ggplot(data = tgc, aes(x = tgc$group, y = tgc$score)) +
geom_bar(stat = 'identity', position = 'dodge') +
geom_errorbar(aes(ymin= tgc$score - ci, ymax= tgc$score  +
ci), width=.2, position=position_dodge(.9))
```


8
6
4
2
0
tgc$score
A
B
C
tgc$group

ok we have learned quite a lot so far!

1 research question / hypothesis?

2 in(dependent) variables?

3a within or between subjects?

3b counterbalancing?

4 how many repetitions/trials?

5 look at raw data

6 look at distributions

7a check for normality

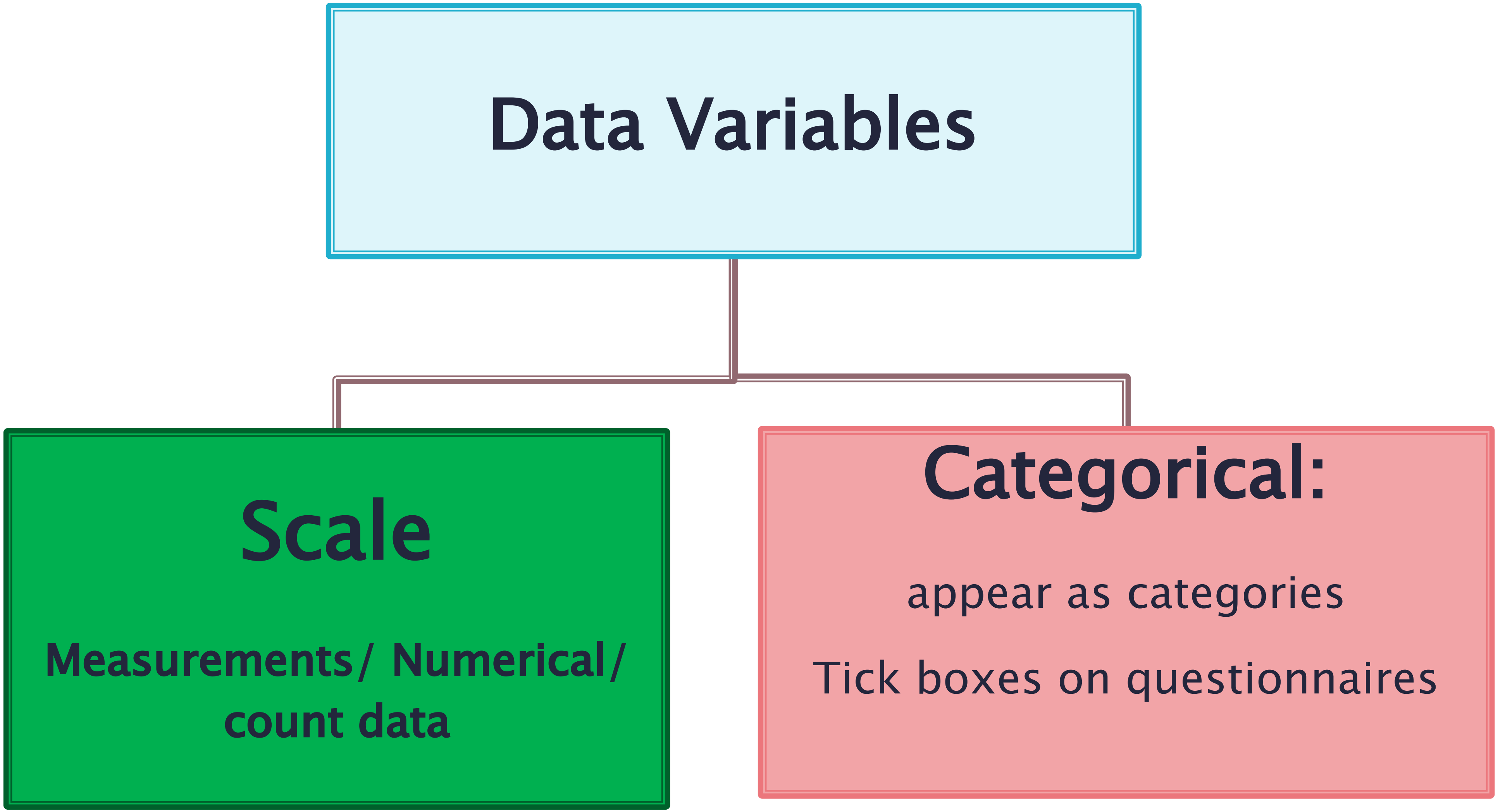
we will see why

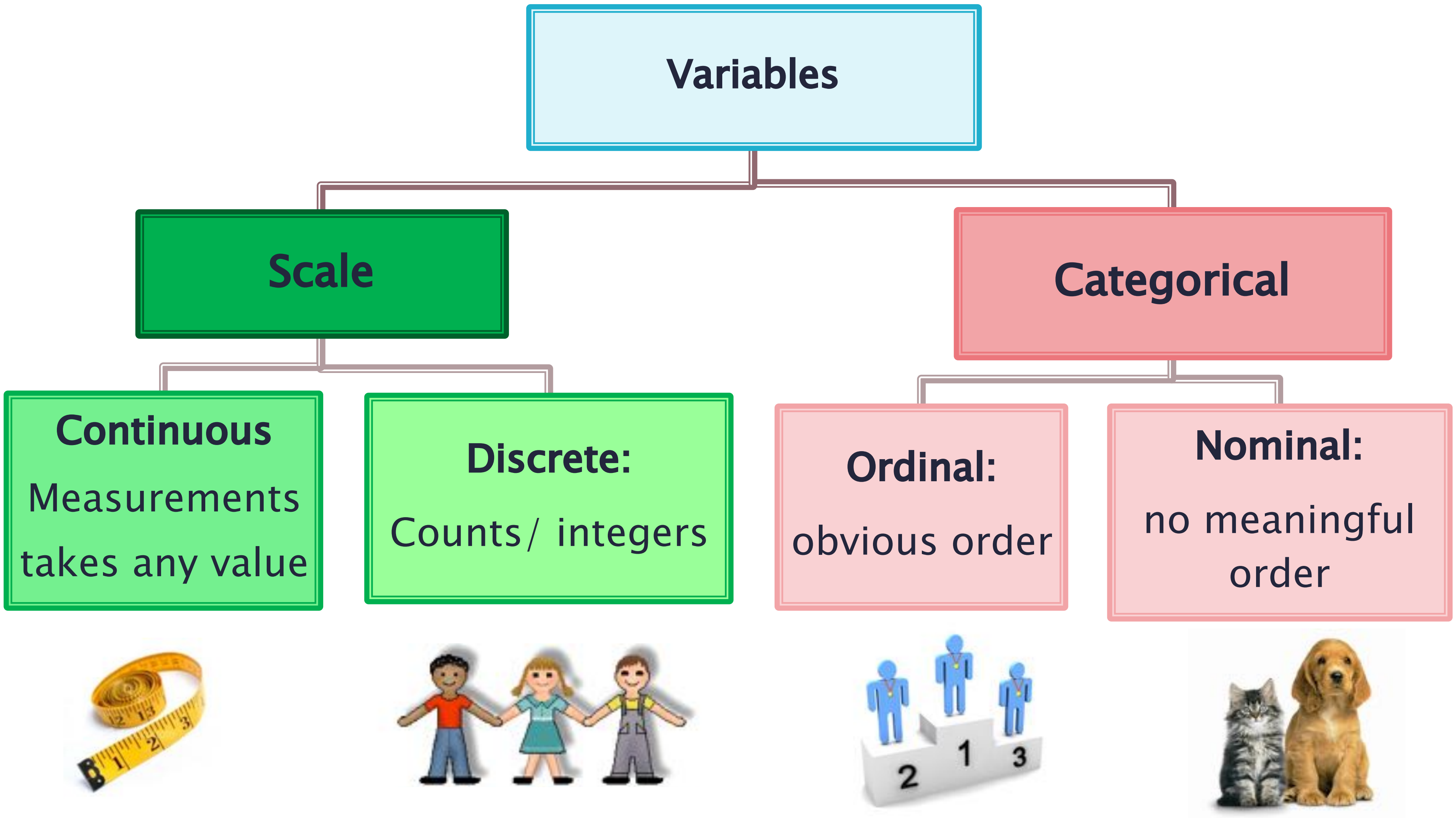
7b run some stats

T-test if 2 group
ANOVA if more

8 conclude

let’s talk about dependent variables


Data Variables
Scale
Measurements/ Numerical/ count data
Categorical:
appear as categories
Tick boxes on questionnaires


Variables
Scale
Categorical
Continuous
Measurements
takes any value
Discrete:
Counts/ integers
Ordinal:
obvious order
Nominal:
no meaningful
order

Q1: What is your favourite subject?

Maths	English	Science	Art	French

Q2: Gender:

Male	Female

Q3: I consider myself to be good at mathematics:

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Q4: Score in a recent mock GCSE maths exam:

Score between 0% and 100%

Q1: What is your favourite subject? **Nominal**

Maths	English	Science	Art	French

Q2: Gender:

Male	Female

Binary/ Nominal

Q3: I consider myself to be good at mathematics:

Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree

Ordinal

Q4: Score in a recent mock GCSE maths exam:

Score between 0% and 100%

Scale

questionnaires as dependent variables ...

Goal is to collect information that is:

Valid

measures the quantity that is supposed to be measured

Reliable

measures the quantity in consistent/reproducible manner

Unbiased

measures the quantity in a way that does not systematically under- or overestimate the true value

Discriminating

can distinguish adequately between respondents for whom the underlying level of the quantity or concept is different

How many cups of coffee or tea do you drink in a day?

No, ask for an answer in only one dimension,
separate the question into two

(1) How many cups of coffee do you drink during a typical day?
(2) How many cups of tea do you drink during a typical day?

What brand of computer do you own?

(A) IBM PC

(B) Apple

Avoid hidden assumptions

Make sure to accommodate all possible answers

Make each response a separate dichotomous item

Do you own an IBM PC? (Circle: Yes or No)

Do you own an Apple computer? (Circle: Yes or No)

Or allow for multiple responses

What brand of computer do you own? (Circle all that apply)

Do not own computer

IBM PC

Apple

Other

Have you had pain in the last week?

[ ] Never [ ] Seldom [ ] Often [ ] Very often

Make sure question and answer options match

Reword either question or answer to match

How often have you had pain in the last week?

[ ] Never [ ] Seldom [ ] Often [ ] Very Often

Where did you grow up?

Country

Farm

City

Avoid questions having non-mutually exclusive answers

Design the question with mutually exclusive options

Where did you grow up?

House in the country

Farm in the country

City

Which one of the following do you think increases a person's chance of having a heart attack the most? (Check one.)

[ ] Smoking[ ] Being overweight [ ] Stress

Encourage to consider each possible response to avoid the uncertainty of whether a missing item may represent either an answer that does not apply or an overlooked item

Which of the following increases the chance of having a heart attack?

Smoking:	[ ] Yes	[ ] No	[ ] Don't know
Being overweight:	[ ] Yes	[ ] No	[ ] Don't know
Stress:	[ ] Yes	[ ] No	[ ] Don't know

On a scale from 1 to 5, how fun did you have using our new system?

1. not at all   2. Not really   3.undecided   4. somewhat   5. very much

Avoid biased questions

Design the question with mutually exclusive options

On a scale from 1 to 5, how would you rate your experience with our new system?

1. not fun at all   2. Not really fun   3.undecided   4. somewhat fun   5. very much fun

Rank from 1 to 3 your preference in beverage

[ ] Tea [ ] Coffee [ ] Orange Jus

Avoid ranking at all cost and rather use Likert scales

On a scale from 1 to 5 rate how much you like the following beverages

Tea:	1. not at all	2. Not really	3.undecided	4. somewhat	5. very much
Coffee:	1. not at all	2. Not really	3.undecided	4. somewhat	5. very much
Orange jus:	1. not at all	2. Not really	3.undecided	4. somewhat	5. very much

if you want to collect subjective metric such as opinions, use **Likert Scale** = ordinal but treated as **continuous variable**

Likert scale::

psychometric response scale primarily used in **questionnaires** to obtain participant’s preferences or degree of agreement with a statement (generally 5pt likert scale, also 7pt)

Agreement

- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

Frequency

- Very Frequently
- Frequently
- Occasionally
- Rarely
- Never

Importance

- Very Important
- Important
- Moderately Important
- Of Little Importance
- Unimportant

Likelihood

- Almost Always True
- Usually True
- Occasionally True
- Usually Not True
- Almost Never True

ok so there are many type of data and so what?

so far we played with data (time, errors, memo) that tends to **follow curve of normal distribution** (typical of human performances)

you could also deal with data that **tends not to follow a normal distribution** (e.g. Likert scale surveys)

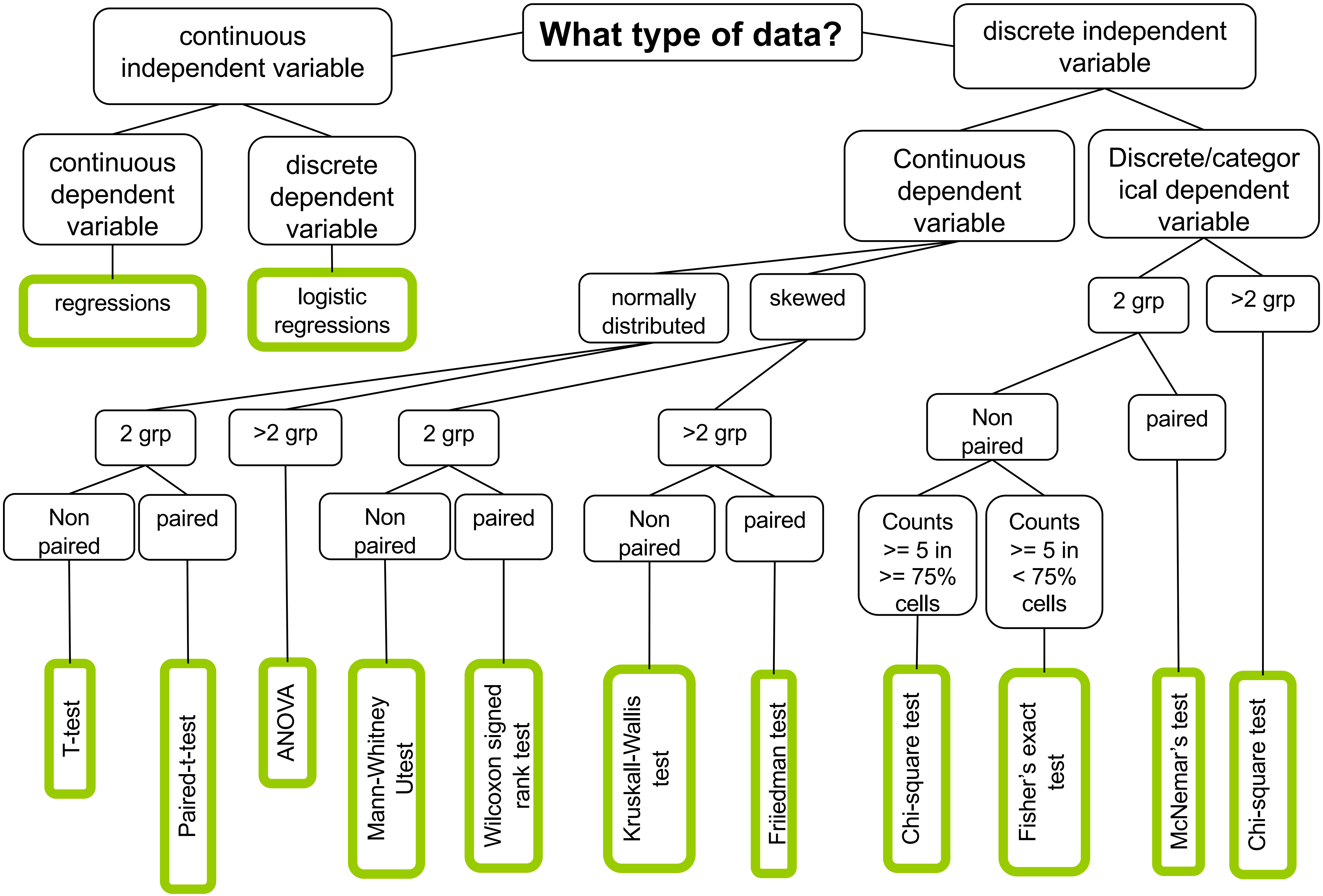

bad news: we cannot use Ttest and Anova

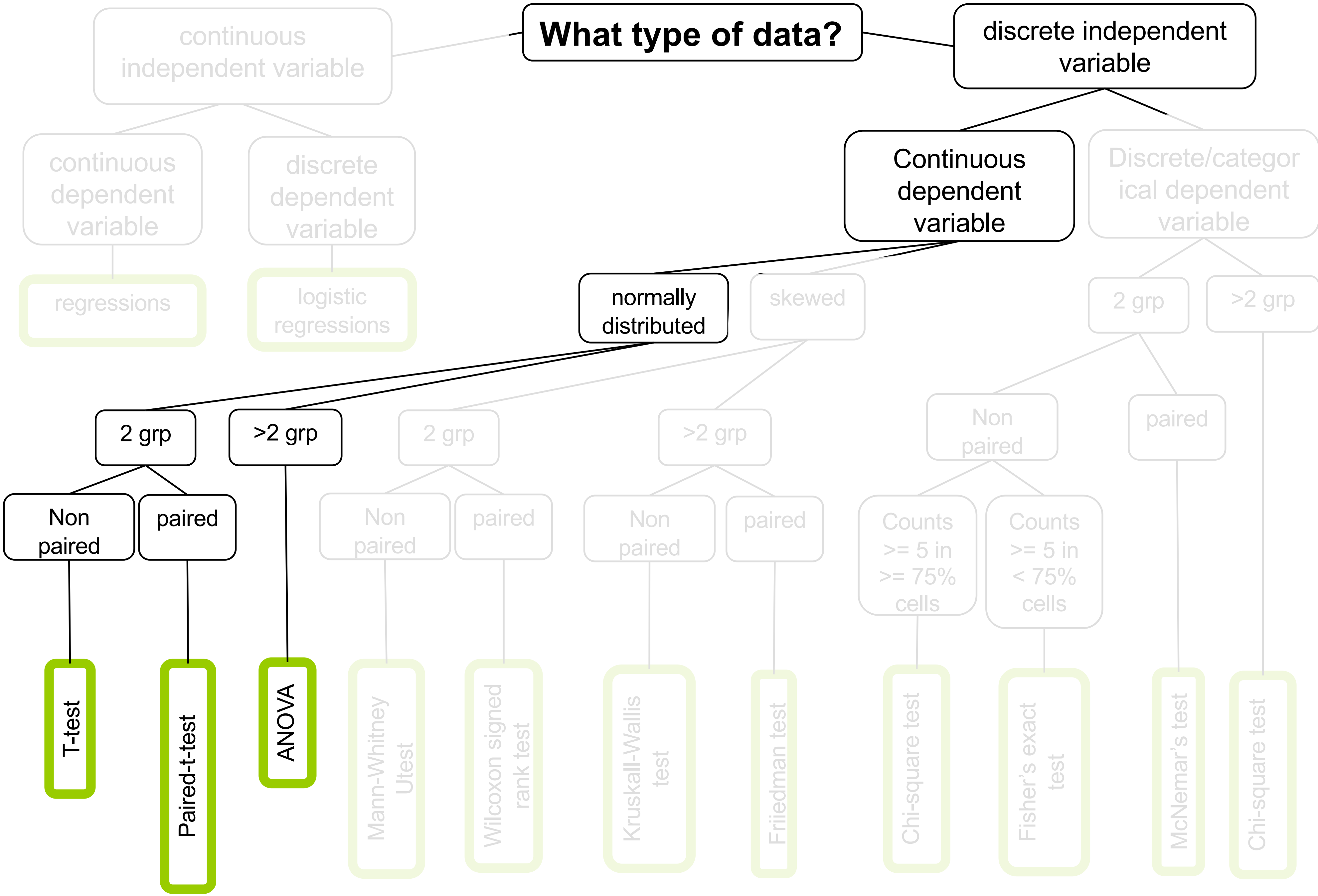
use parametric tests (ttest, anova)

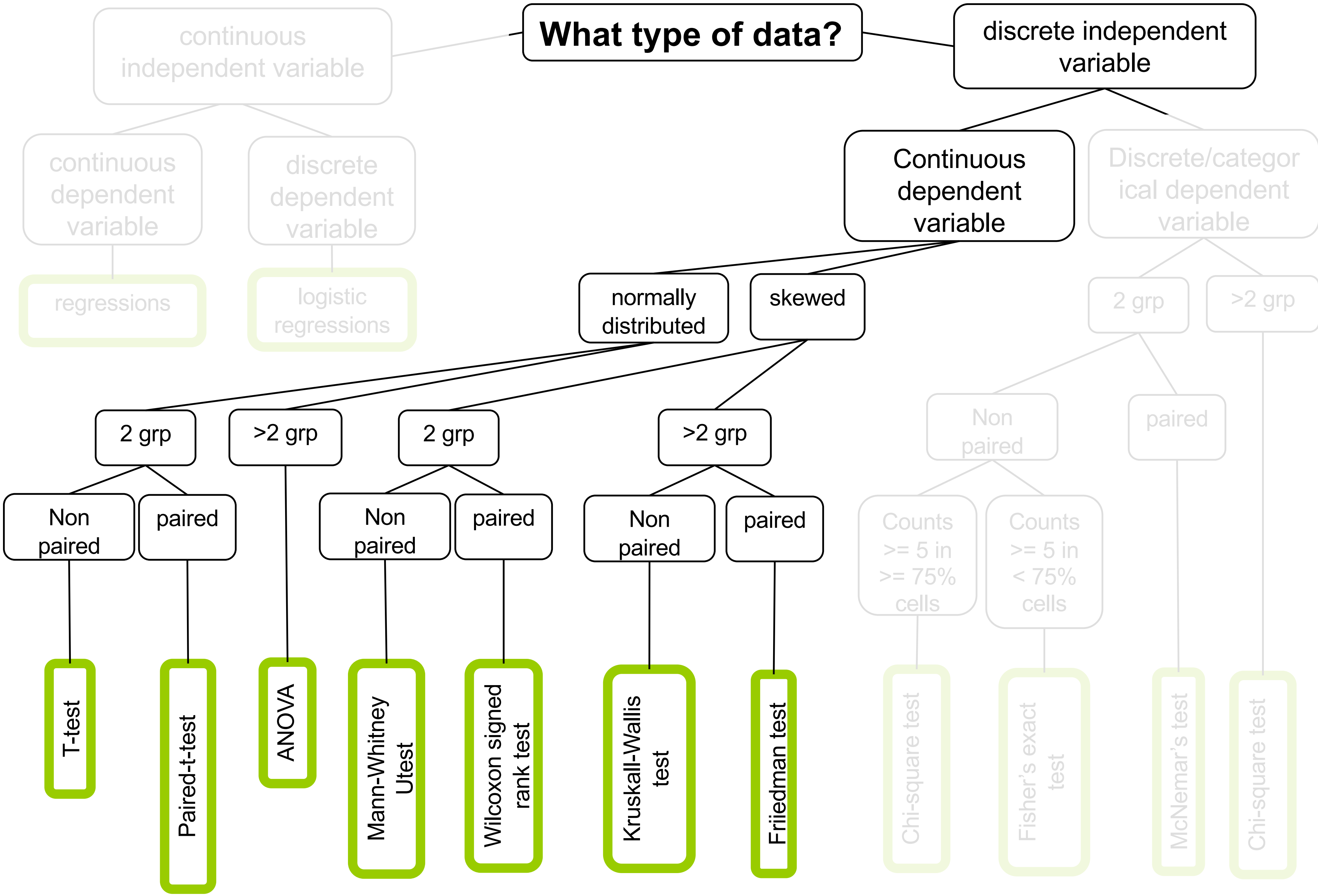
so far we played data (time, errors, memo)
that tends to **follow curve of normal distribution**
(typical of human performances)

you could also deal with data
that **tends not to follow a normal distribution** (e.g.
Likert scale surveys)

use non-parametric tests


What type of data?
continuous independent variable
discrete independent variable
continuous dependent variable
discrete dependent variable
regressions
logistic regressions
Continuous dependent variable
Discrete/categorical dependent variable
normally distributed
skewed
2 grp
>2 grp
2 grp
>2 grp
2 grp
>2 grp
Non paired
paired
Non paired
paired
Non paired
paired
Non paired
paired
Counts >= 5 in >= 75% cells
Counts >= 5 in < 75% cells
T-test
Paired-t-test
ANOVA
Mann-Whitney Utest
Wilcoxon signed rank test
Kruskall-Wallis test
Friiedman test
Chi-square test
Fisher's exact test
McNemar's test
Chi-square test


What type of data?
continuous independent variable
discrete independent variable
continuous dependent variable
discrete dependent variable
regressions
logistic regressions
Continuous dependent variable
Discrete/categorical dependent variable
normally distributed
skewed
2 grp
>2 grp
2 grp
>2 grp
2 grp
>2 grp
Non paired
paired
Non paired
paired
Non paired
paired
Non paired
paired
Counts >= 5 in >= 75% cells
Counts >= 5 in < 75% cells
T-test
Paired-t-test
ANOVA
Mann-Whitney Utest
Wilcoxon signed rank test
Kruskall-Wallis test
Friedman test
Chi-square test
Fisher's exact test
McNemar's test
Chi-square test



What type of data?
continuous independent variable
discrete independent variable
continuous dependent variable
discrete dependent variable
regressions
logistic regressions
Continuous dependent variable
Discrete/categorical dependent variable
normally distributed
skewed
2 grp
>2 grp
2 grp
>2 grp
Non paired
paired
Non paired
paired
Non paired
paired
T-test
Paired-t-test
ANOVA
Mann-Whitney Utest
Wilcoxon signed rank test
Kruskall-Wallis test
Friedman test
2 grp
>2 grp
Non paired
paired
Counts >= 5 in >= 75% cells
Counts >= 5 in < 75% cells
Chi-square test
Fisher's exact test
McNemar's test
Chi-square test

the best thing to do is to test if your data follow a normal distribution or not first before running the stats

… we will look at this in two lectures

summary

1 research question / hypothesis?

2 in(dependant) variables?

3a within or between subjects?

3b counterbalancing?

4 how many repetitions/trials?

5 look at raw data

6 look at distributions

7a we will see why
check for normality

7b run some stats

8 conclude

design the experiment in such way that the results will be **easy to analyze**

be sure you will be **able to perform the statistical** analysis

there are many R tutorials online!

1. Explain the eight steps to design and analyze an experiment
2. Explain what is a within or between subject experiment
3. Explain what is a controlled variable or a confounding variable
4. Explain the difference between correlation and causality
5. Identify different types of variables
6. Understand when to use a t-test, when to use an Anova
7. Explain what is a Likert scale in questionnaires
8. Explain when to use non-parametric tests

take away

end