What interspersion was needed for **our pulse experiment?**

What interspersion would be needed for **the direct estimate version?**

Three alternatives for the pulse experiment

							EU	Replicate
1)		Sit		Stand		Sit	Person	None
	Jill	X	Bob	X	Amy	X		
2)		Jill		Bob		Amy	Person:Trial	Person
	T1	Sit	T1	Stand	T1	Sit		
	T2	Stand	T2	Sit	T2	Stand		
3)		Sit		Stand		Sit	Person	None
	Jill	X T1 X T2	Bob	X T1 X T2	Amy	X T1 X T2		

Experimental Unit

The **smallest** unit of experimental material to which a **single treatment** (or treatment combination) is assigned by the experimenter and which is dealt with **independently** of other such systems **under that treatment** at **all stages in the experiment** at which important variation may enter.

Each experimental unit get its treatment **independently**

Each experimental unit is **equally likely** to be assigned each treatment

Experimental units shouldn't **interfere** with each other

Experimental units should be **randomly** selected from a **reference population**

Replicates

Units exposed to all treatment levels where we can construct a direct treatment effect estimate

Three alternatives for the pulse experiment

							EU	**Replicate**
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy		
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

		Sit		Stand		Sit		
3)	Jill	X T1 X T2	Bob	X T1 X T2	Amy	X T1 X T2	Person	None

How do we analyze each experiment?

Analytically describe the design

How are treatment effect estimates constructed?

What are the sources of confusion?

controlled and un-controlled

how does each affect the precision of the results?

Empirically analyze data collected from the design

How do we communicate the design to *R*?

R's calculations **do not** follow our analytical processes

How do we estimate the treatment effect?

		Jill	Bob	Amy	**EU**	**Replicate**
2)	T1	Sit	Stand	Sit	Person:Trial	Person
	T2	Stand	Sit	Stand		

Collect 40 people

Measure each person 1x in each treatment, calculate the difference

$$y_{A1}, y_{B1} \rightarrow d_1$$

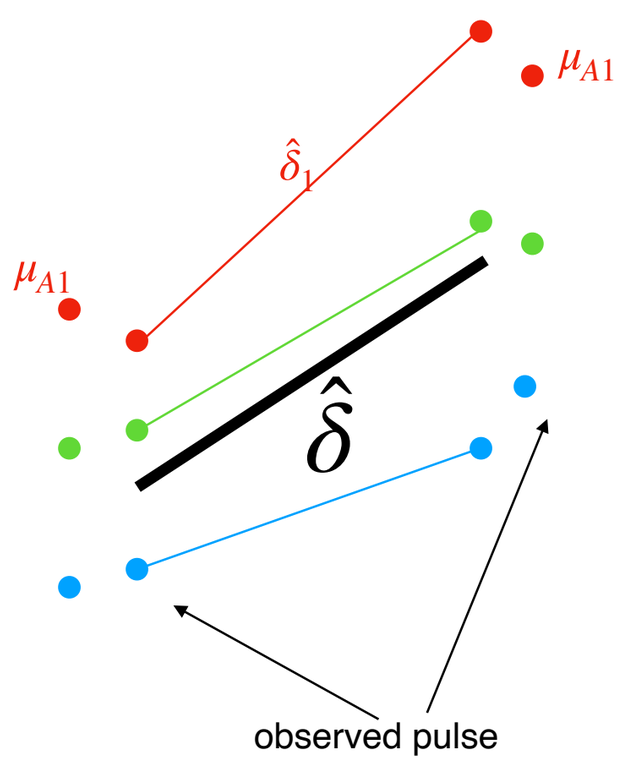
Estimate the treatment effect for each person

$$\hat{\delta}_1$$

Estimate the average treatment effect

$$\hat{\delta}_{B-A} = \frac{1}{n}\sum \hat{\delta}_j$$

True Pulse



Sit	Stand
A	B

Direct estimate of δ

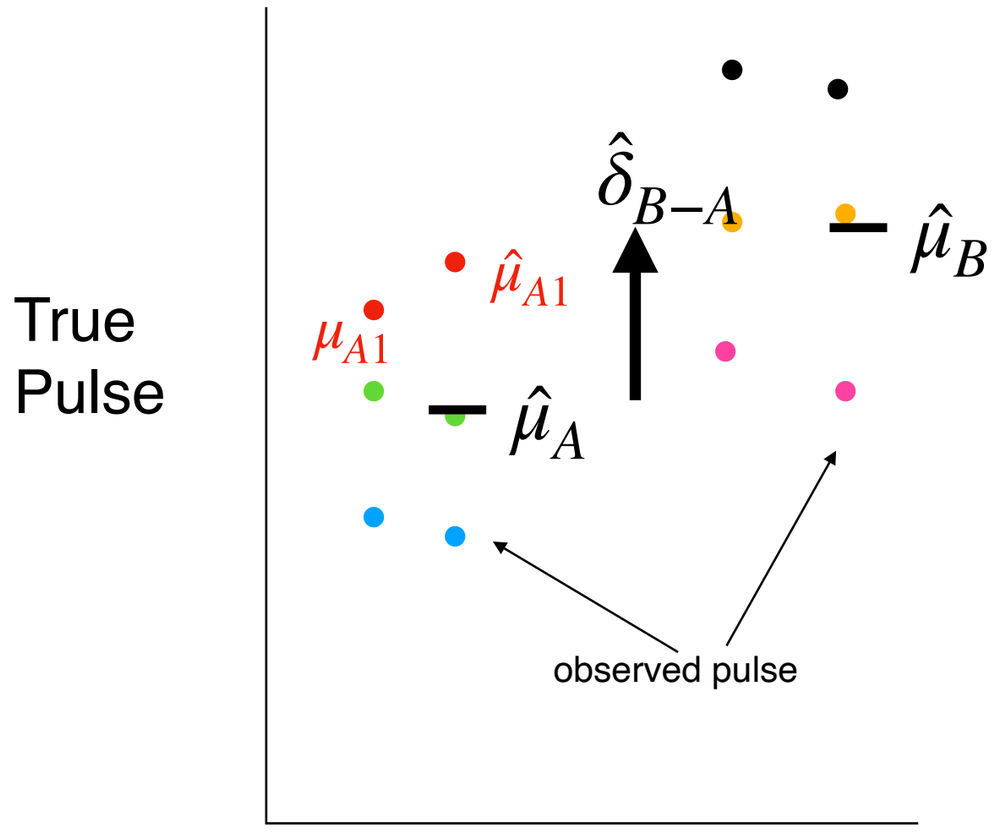
How do we estimate the treatment effect?

							EU
		Sit		Stand		Sit	
1)	Jill	X	Bob	X	Amy	X	Person

Collect 40 people for Sitting group and 40 people for standing group. These are our EU

Measure each person 1x after applying the appropriate treatment level

$$y_{A1}, y_{B2}, \cdots$$



Estimate the average pulse of each group

$$\hat{\mu}_A = \frac{1}{n_A}\sum \hat{\mu}_{Aj} \qquad \hat{\mu}_B = \frac{1}{n_B}\sum \hat{\mu}_{Bj}$$

Estimate the average treatment effect

$$\hat{\delta}_{B-A} = \hat{\mu}_B - \hat{\mu}_A$$

Indirect estimate of δ

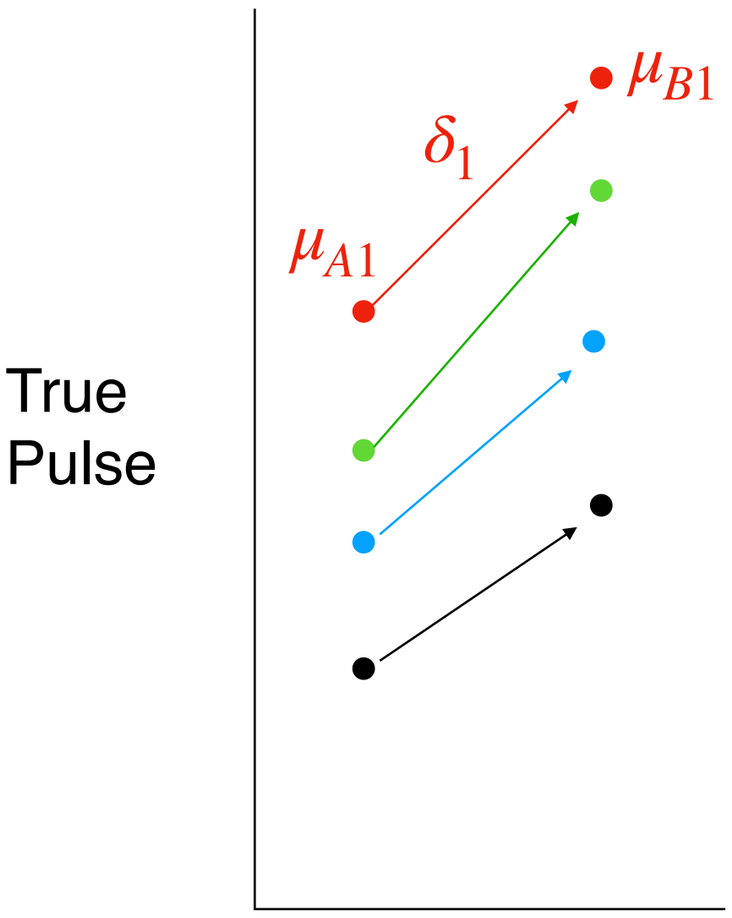
Through direct estimates of μ_B and μ_A

Why are these both **valid** methods to estimate δ?

							EU	**Replicate**
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy		
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

Say this was **the whole population …**



EU	**Sit**	**Stand**	δ_j
p1	75	82	7
p2	63	65	2
p3	69	83	14
p4	60	72	12
μ_i	66.75	75.5	**8.75**

1) Calculate the treatment effects for each person

2) Calculate the **mean** treatment effect

3) Calculate the **means** of each **treatment level**

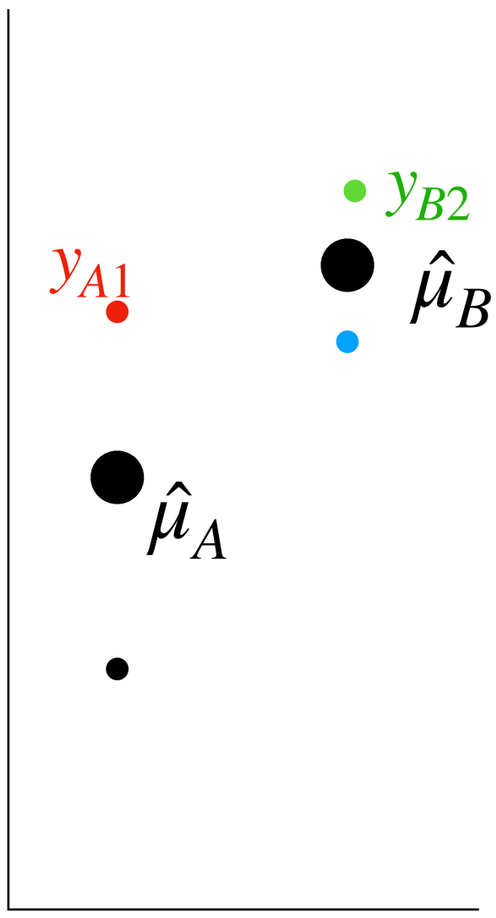
4) Calculate the **difference between means**

Why are these both **valid** methods to estimate δ?

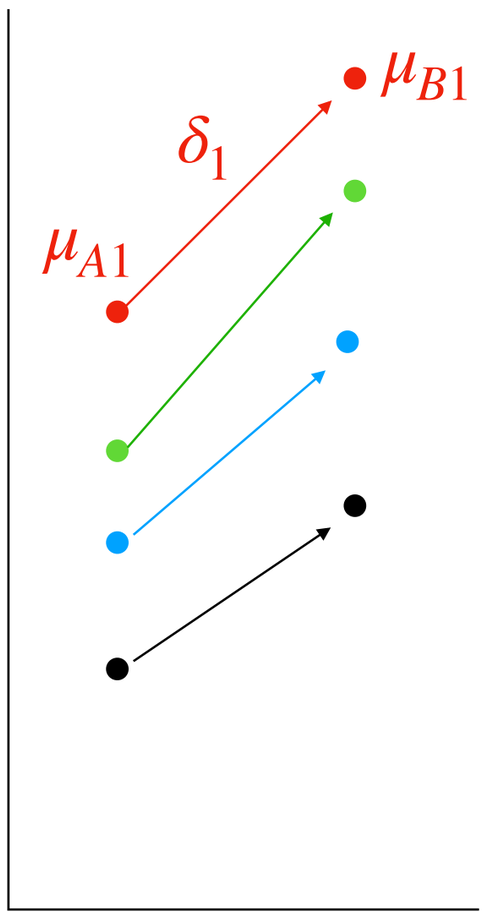
							EU	**Replicate**
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy			
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

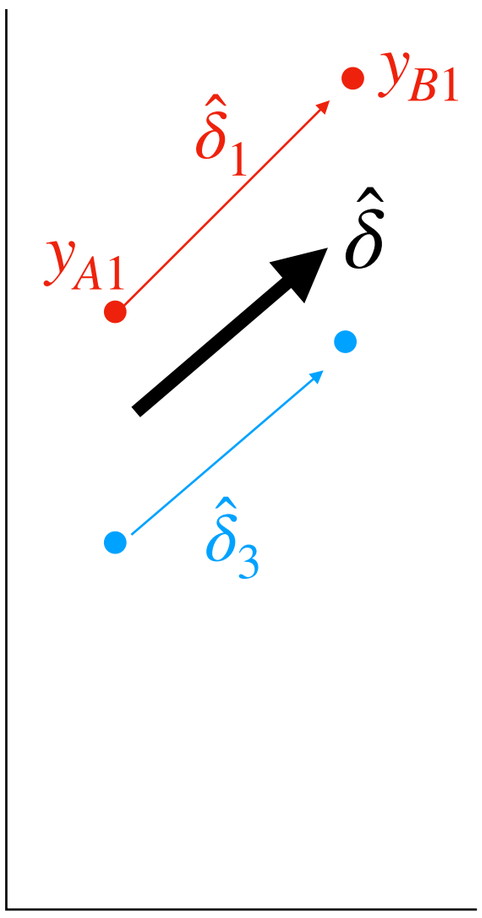
Design 1
Indirect



True
Pulse



Design 2
Direct



$\hat{\mu}_i$ has sampling error due to:

missing some individuals

measurement error

But each is **unbiased** for μ_i

And errors are **uncorrelated**

$\hat{\delta}$ has sampling error due to:

missing some individuals

measurement error

But it is **unbiased** for δ

Why are these both **valid** methods to estimate δ?

							EU	**Replicate**
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy			
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

Both designs are **valid** because:

$$\delta = \frac{\sum \delta_j}{N}$$

$$= \frac{\sum (\mu_{Bj} - \mu_{Aj})}{N}$$

$$= \frac{\sum \mu_{Bj}}{N} - \frac{\sum \mu_{Aj}}{N}$$

$$= \mu_B - \mu_A$$

Mean difference equals the **difference of the means**

Three alternatives for the pulse experiment

							EU	**Replicate**
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy		
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

		Sit		Stand		Sit		
3)	Jill	X T1 X T2	Bob	X T1 X T2	Amy	X T1 X T2	Person	None

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Three alternatives for the pulse experiment

							EU	Replicate
		Sit		Stand		Sit		
1)	Jill	X	Bob	X	Amy	X	Person	None

		Jill		Bob		Amy		
2)	T1	Sit	T1	Stand	T1	Sit	Person:Trial	Person
	T2	Stand	T2	Sit	T2	Stand		

		Sit		Stand		Sit		
3)	Jill	X T1 X T2	Bob	X T1 X T2	Amy	X T1 X T2	Person	None

Design Table

Structure	Variable	Type	#levels	Replicate	EU
Treatment					
Design					
Response					

Describe how our Experimental Design relates to our Data

Translate the table into R code

Experiment 1: 1 measurement per person

							# people	# measures	#EU
		Sit		Stand		Sit			
1)	Jill	X	Bob	X	Amy	X	80	80	80

Person	Posture	Pulse
Jill	Sit	60
Bob	Stand	72
Amy	Sit	106
⋮		

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	None	Person
Design	Person	Cat	80		
Response	Pulse	Num	80		

Each column of your table = Variable

Type = Categorical or Numeric

#levels = number of unique values in the column of the data

Only Treatment variables get Replicates and EU

Experiment 2: each person measured in each treatment

2)

	Jill	Bob	Amy
T1	Sit	Stand	Sit
T2	Stand	Sit	Stand

# people	# measures	#EU
40	80	80

Person	Posture	Pulse	Trial	Person:Trial
Jill	Sit	60	T1	Jill:T1
Jill	Stand	74	T2	Jill:T2
Bob	Stand	72	T1	Bob:T1
Bob	Sit	78	T2	Bob:T2
Amy	Sit	106	T1	Amy:T1
Amy	Stand	109	T2	Amy:T2
⋮				

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	Person	Person:Trial
Design	Person	Cat	40		
	Trial	Cat	2		
	Person:Trial	Cat	80		
Response	Pulse	Num	80		

“Person:Trial” is a **Combination Variable**

We don’t have to create it in our data table (but we can)

Experiment 3: each person measured 2x in one treatment

3)

	Sit		Stand		Sit		# people	# measures	#EU
Jill	X	T1	X	T1	X	T1	40	80	40
	X	T2	X	T2	X	T2			

Person	Posture	Pulse	Trial	Person:Trial
Jill	Sit	60	T1	Jill:T1
Jill	Sit	64	T2	Jill:T2
Bob	Stand	72	T1	Bob:T1
Bob	Stand	68	T2	Bob:T2
Amy	Sit	106	T1	Amy:T1
Amy	Sit	112	T2	Amy:T2
⋮				

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	None	Person
Design	Person	Cat	40		
	Trial	Cat	2		
	Person:Trial	Cat	80		
Response	Pulse	Num	80		

The first 4 columns are the same!

Fitting models in R

1) Write the model

2) Pass it to the function to fit the model: **lm()** or **lmer()**

3) Pass the result to a function to get estimates, SE, CI, etc

emmeans(), **contrasts()**, etc

Writing the model

1) Response ~ model

model: every variable in Treatment + Design

with # levels < # responses

combined with “+”

2) Any variable that is a **Replicate** or **EU** gets declared with (1|X)

+ Variable => + (1|Variable)

call these “random”

Replicates are declared as + (1|Replicate:Treatment)

3) If any random variable is included, use lmer(). Otherwise use lm()

1) Response ~ model

model: every variable in Treatment + Design, combined with “+”

with # levels < # responses

2) Any variable that is a **Replicate** or **EU** gets declared with (1|X)

+ Variable => + (1|Variable)

call these “random”

Replicates are declared as + (1|Replicate:Treatment)

3) If any random variable is included, use lmer(). Otherwise use lm()

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	None	Person
Design	Person	Cat	80		
Response	Pulse	Num	80		

lm(Pulse ~ Posture)

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	Person	Person:Trial
Design	Person	Cat	40		
	Trial	Cat	2		
	Person:Trial	Cat	80		
Response	Pulse	Num	80		

lm(Pulse ~ Posture + Person + Trial)

For Tuesday:

3)

	Sit	Stand	Sit	# people	# measures	#EU
Jill	X T1	Bob X T1	Amy X T1	40	80	80
	X T2	X T2	X T2			

Structure	Variable	Type	#levels	Replicate	EU
Treatment	Posture	Cat	2	None	Person
Design	Person	Cat	40		
	Trial	Cat	2		
	Person:Trial	Cat	80		
Response	Pulse	Num	80		

Write the model for Design 3

Read the remainder of Hurlbert 1984

What type of **pseudoreplication** are we committing if we don’t declare Person as Random in this experiment?