Programming III

Bootstrapping for hypothesis testing

Testing hypotheses with bootstrapping

- We used randomization testing previously to test hypotheses
- Can also bootstrap the difference between groups
- If the 95% CI of the differences doesn't include 0, the groups are different

Learning in metamorphic moths

- *Manduca sexta* – metamorphosis from caterpillar to moth
- Can be trained as caterpillars
  - Put them in a container with an odorant (ethyl acetate, EA) in one end
  - Deliver an uncomfortable shock if they move toward EA
  - They develop an aversion to EA
- Caterpillars metamorphose → un-differentiate their body tissues, re-differentiate as adults
- Question: do they retain their aversion to EA as adults?

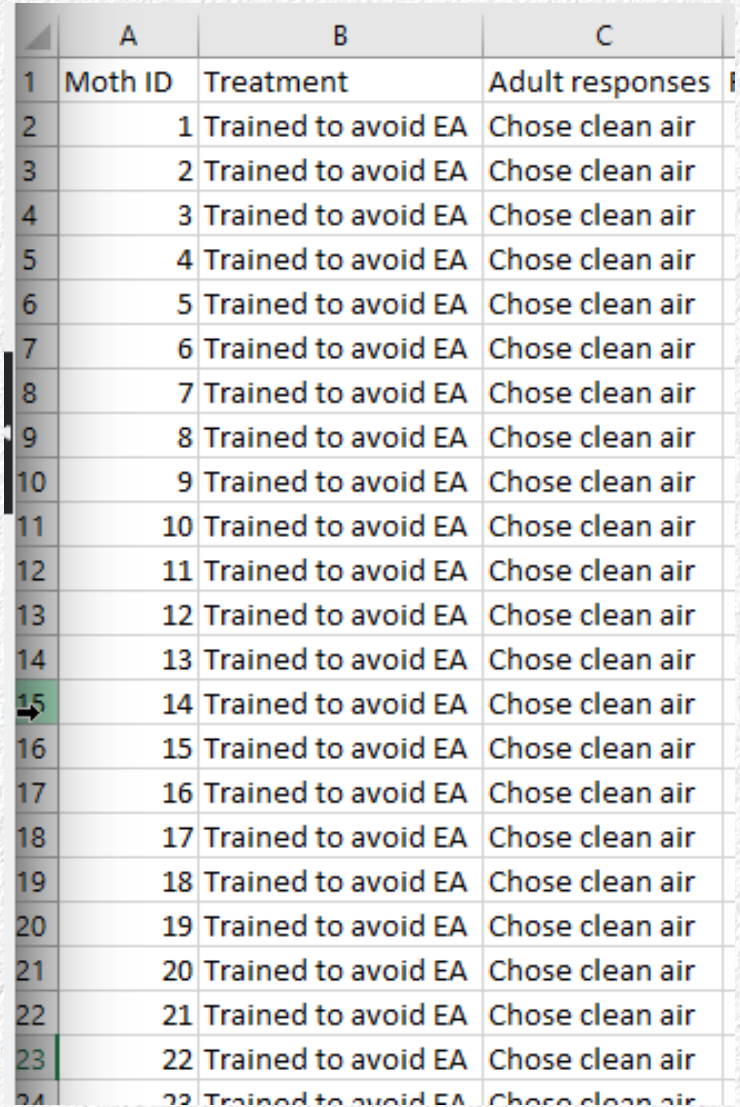
The data – summarized

- What would we expect if the training didn't last to adulthood?
- What does it look like?
- How do we know this isn't just random chance?

	Caterpillar	
Adult response	Control	Trained to avoid EA
Chose clean air	25	32
Chose EA air	21	9
Total	46	41

The data - un-summarized

- For each moth tested, know the treatment and the response
- Can count these up in a Pivot Table...



	A	B	C
1	Moth ID	Treatment	Adult responses
2	1	Trained to avoid EA	Chose clean air
3	2	Trained to avoid EA	Chose clean air
4	3	Trained to avoid EA	Chose clean air
5	4	Trained to avoid EA	Chose clean air
6	5	Trained to avoid EA	Chose clean air
7	6	Trained to avoid EA	Chose clean air
8	7	Trained to avoid EA	Chose clean air
9	8	Trained to avoid EA	Chose clean air
10	9	Trained to avoid EA	Chose clean air
11	10	Trained to avoid EA	Chose clean air
12	11	Trained to avoid EA	Chose clean air
13	12	Trained to avoid EA	Chose clean air
14	13	Trained to avoid EA	Chose clean air
15	14	Trained to avoid EA	Chose clean air
16	15	Trained to avoid EA	Chose clean air
17	16	Trained to avoid EA	Chose clean air
18	17	Trained to avoid EA	Chose clean air
19	18	Trained to avoid EA	Chose clean air
20	19	Trained to avoid EA	Chose clean air
21	20	Trained to avoid EA	Chose clean air
22	21	Trained to avoid EA	Chose clean air
23	22	Trained to avoid EA	Chose clean air
24	23	Trained to avoid EA	Chose clean air

	A	B	C	F	G	H	I	J	K
1	Moth ID	Treatment	Adult responses			**Count of Adult responses**	**Column Labels**		
2	1	Trained to avoid EA	Chose clean air			**Row Labels**	**Control**	**Trained to avoid EA**	**Grand Total**
3	2	Trained to avoid EA	Chose clean air			Chose clean air	25	32	57
4	3	Trained to avoid EA	Chose clean air			Chose EA air	21	9	30
5	4	Trained to avoid EA	Chose clean air			**Grand Total**	**46**	**41**	**87**
6	5	Trained to avoid EA	Chose clean air						
7	6	Trained to avoid EA	Chose clean air						
8	7	Trained to avoid EA	Chose clean air						
9	8	Trained to avoid EA	Chose clean air						
10	9	Trained to avoid EA	Chose clean air						
11	10	Trained to avoid EA	Chose clean air						
12	11	Trained to avoid EA	Chose clean air						
13	12	Trained to avoid EA	Chose clean air						
14	13	Trained to avoid EA	Chose clean air						
15	14	Trained to avoid EA	Chose clean air						
16	15	Trained to avoid EA	Chose clean air						
17	16	Trained to avoid EA	Chose clean air						
18	17	Trained to avoid EA	Chose clean air						
19	18	Trained to avoid EA	Chose clean air						
20	19	Trained to avoid EA	Chose clean air						
21	20	Trained to avoid EA	Chose clean air						
22	21	Trained to avoid EA	Chose clean air						
23	22	Trained to avoid EA	Chose clean air						

Calculate an odds ratio for the responses

	A	B	C	F	G	H	I	J	K
1	Moth ID	Treatment	Adult responses			**Count of Adult responses**	**Column Labels**		
2	1	Trained to avoid EA	Chose clean air			**Row Labels**	**Control**	**Trained to avoid EA**	**Grand Total**
3	2	Trained to avoid EA	Chose clean air			Chose clean air	25	32	57
4	3	Trained to avoid EA	Chose clean air			Chose EA air	21	9	30
5	4	Trained to avoid EA	Chose clean air			**Grand Total**	**46**	**41**	**87**
6	5	Trained to avoid EA	Chose clean air						
7	6	Trained to avoid EA	Chose clean air						
8	7	Trained to avoid EA	Chose clean air			Odds of choosing clean air	1.19047619	3.555555556	
9	8	Trained to avoid EA	Chose clean air						
10	9	Trained to avoid EA	Chose clean air			Odds ratio	2.986666667		
11	10	Trained to avoid EA	Chose clean air						
12	11	Trained to avoid EA	Chose clean air						
13	12	Trained to avoid EA	Chose clean air						
14	13	Trained to avoid EA	Chose clean air						
15	14	Trained to avoid EA	Chose clean air						
16	15	Trained to avoid EA	Chose clean air						
17	16	Trained to avoid EA	Chose clean air						
18	17	Trained to avoid EA	Chose clean air						
19	18	Trained to avoid EA	Chose clean air						
20	19	Trained to avoid EA	Chose clean air						
21	20	Trained to avoid EA	Chose clean air						
22	21	Trained to avoid EA	Chose clean air						
23	22	Trained to avoid EA	Chose clean air						
24	23	Trained to avoid EA	Chose clean air						

Record the observed odds ratio

Then select a bootstrap sample, update the Pivot Table...

	A	B	C	D	E	F	G	H	I	J	K
1	Moth ID	Treatment	Adult responses	Random numbers	Bootstrap sample			**Count of Bootstrap sample**	**Column Labels**		
2	1	Trained to avoid EA	Chose clean air	30	Chose clean air			**Row Labels**	**Control**	**Trained to avoid EA**	**Grand Total**
3	2	Trained to avoid EA	Chose clean air	19	Chose clean air			Chose clean air	32	26	58
4	3	Trained to avoid EA	Chose clean air	36	Chose EA air			Chose EA air	14	15	29
5	4	Trained to avoid EA	Chose clean air	38	Chose EA air			**Grand Total**	**46**	**41**	**87**
6	5	Trained to avoid EA	Chose clean air	23	Chose clean air						
7	6	Trained to avoid EA	Chose clean air	28	Chose clean air						
8	7	Trained to avoid EA	Chose clean air	27	Chose clean air			Odds of choosing clean air	2.285714286	1.733333333	
9	8	Trained to avoid EA	Chose clean air	28	Chose clean air						
10	9	Trained to avoid EA	Chose clean air	6	Chose clean air			Odds ratio	0.758333333		
11	10	Trained to avoid EA	Chose clean air	33	Chose EA air						
12	11	Trained to avoid EA	Chose clean air	18	Chose clean air			Observed odds ratio	2.986666667		
13	12	Trained to avoid EA	Chose clean air	3	Chose clean air						
14	13	Trained to avoid EA	Chose clean air	36	Chose EA air						
15	14	Trained to avoid EA	Chose clean air	18	Chose clean air						
16	15	Trained to avoid EA	Chose clean air	23	Chose clean air						
17	16	Trained to avoid EA	Chose clean air	20	Chose clean air						
18	17	Trained to avoid EA	Chose clean air	5	Chose clean air						
19	18	Trained to avoid EA	Chose clean air	1	Chose clean air						
20	19	Trained to avoid EA	Chose clean air	24	Chose clean air						
21	20	Trained to avoid EA	Chose clean air	29	Chose clean air						
22	21	Trained to avoid EA	Chose clean air	35	Chose EA air						
23	22	Trained to avoid EA	Chose clean air	27	Chose clean air						

This bootstrap sample doesn't have the big difference between control and trained

Now we just need a loop to repeat 1000 times...

```
Sub BootstrapOdds()
'
' BootstrapOdds Macro
'
' Keyboard Shortcut: Ctrl+Shift+O
'

Application.ScreenUpdating = False

For i = 1 To 1000
    ActiveSheet.PivotTables("PivotTable1").PivotCache.Refresh
    Range("M" & i + 1) = Range("I10").Value
Next i

Columns("M").Sort key1:=Range("M2"), order1:=xlAscending, Header:=xlYes

Range("I13") = Range("M26").Value
Range("I14") = Range("M976").Value

Application.ScreenUpdating = True

End Sub
```

Make it fast!

Do it 1000 times

It – that is, refresh the table, which selects a new bootstrap sample

Enter the odds ratio from I10 into column M, row i+1

Sort, then find the lower and upper limits

Screen updating back on

Results and interpretation

Observed odds ratio	2.986666667
Lower	1.254901961
Upper	9.743589744
Since the lower limit is greater than 1 butterflies remember what they learn as caterpillars.	

Interval does not include 1, so caterpillars trained to avoid EA continue to as adults

Your turn

- We’ll write this program as today’s exercise