

Lecture 35

Data: flipped classrooms?

Data set has 375 rows (one per student), and the following variables:

- `professor`: which professor taught the class (1 – 15)
- `style`: which teaching style the professor used (no flip, some flip, fully flipped)
- `score`: the student's score on the final exam

Inference with linear models

$$\text{Score}_i = \beta_0 + \beta_1 \text{SomeFlipped}_i + \beta_2 \text{FullyFlipped}_i + \varepsilon_i$$

Research question: Is there a relationship between teaching style and student score?

What are my null and alternative hypotheses, in terms of one or more model parameters?

Inference with linear models

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Research question: Is there a relationship between teaching style and student score?

$$H_0 : \beta_1 = \beta_2 = 0$$

$$H_A : \text{at least one of } \beta_1, \beta_2 \neq 0$$

What test would I use to test these hypotheses?

F tests

$$\text{Score}_i = \beta_0 + \beta_1 \text{SomeFlipped}_i + \beta_2 \text{FullyFlipped}_i + \varepsilon_i$$

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$$H_0 : \beta_1 = \beta_2 = 0$$

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What are my degrees of freedom for the F test?

F tests for mixed effects models

$$\text{Score}_{ij} = \beta_0 + \beta_1 \text{SomeFlipped}_i + \beta_2 \text{FullyFlipped}_i + u_i + \varepsilon_{ij}$$

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F tests for mixed effects models

$$\text{Score}_{ij} = \beta_0 + \beta_1 \text{SomeFlipped}_i + \beta_2 \text{FullyFlipped}_i + u_i + \varepsilon_{ij}$$

Research question: Is there a relationship between teaching style and student score?

$$H_0 : \beta_1 = \beta_2 = 0$$

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Test: We will use an F test again

- numerator df = number of parameters tested = 2
- denominator df = ??

What *are* degrees of freedom?

Denominator degrees of freedom for mixed models

$$\text{Score}_{ij} = \beta_0 + \beta_1 \text{SomeFlipped}_i + \beta_2 \text{FullyFlipped}_i + u_i + \varepsilon_{ij}$$

$$H_0 : \beta_1 = \beta_2 = 0 \quad H_A : \text{at least one of } \beta_1, \beta_2 \neq 0$$

Test: We will use an F test again

- numerator df = number of parameters tested = 2
- denominator df =

number of independent observations – number of parameter

Are all observations independent?

Denominator degrees of freedom for mixed models

Approximating the degrees of freedom

```
1 groups <- rep(1:30, each=10)
2 sigma_u <- 0.1
3 sigma_e <- 0.5
4
5 u <- rnorm(30, sd=sigma_u)
6 x1 <- rnorm(300)
7 y <- 1 + u[groups] + 0.5*x1 + rnorm(300, sd=sigma_e)
8
9 m1 <- lmer(y ~ x1 + (1|groups))
10 summary(m1)$coefficients
```

	Estimate	Std. Error	df	t value	Pr(> t)
(Intercept)	0.9435989	0.03195537	28.9317	29.52865	3.736113e-23
x1	0.4560607	0.02533352	293.2377	18.00226	2.547871e-49

Approximating the degrees of freedom

```
1 groups <- rep(1:30, each=10)
2 sigma_u <- 1
3 sigma_e <- 0.5
4
5 u <- rnorm(30, sd=sigma_u)
6 x1 <- rnorm(300)
7 y <- 1 + u[groups] + 0.5*x1 + rnorm(300, sd=sigma_e)
8
9 m1 <- lmer(y ~ x1 + (1|groups))
10 summary(m1)$coefficients
```

	Estimate	Std. Error	df	t value	Pr(> t)
(Intercept)	1.2545954	0.18763891	29.00394	6.686222	2.469481e-07
x1	0.5155989	0.03198145	270.54591	16.121812	1.920600e-41

Class activity

<https://sta712->

[f23.github.io/class_activities/ca_lecture_35.html](https://sta712-f23.github.io/class_activities/ca_lecture_35.html)

