# Test 02: Numeric Y vs Numeric X

Richard

2024-01-01

# Load required packages

```
library(tidyverse) # if you're using macOS, you can run: library(dp
library(skimr)
library(ggplot2)
```

# Prepare Data

Please read the intro about data at here

```
Hsb = read_csv("data/raw/hsb.csv")
Hsb = Hsb %>%
  mutate(
    race = as.factor(race),
    schtyp = as.factor(schtyp),
    prog = as.factor(prog)
  )
```

# Numeric variables

- In general, we deal with numeric variables all the time
  - e.g., temperature, rain volume, salary, …
- It is rich value and contains more information than categorical variables
- Sometimes, we want to find the **relation** between two numeric variables e.g., “temperature and our electricity bills”, “how far you live to the downtown and your income”, …
- A **relation** does not mean a **causality**

# Relation/Correlation vs Causality

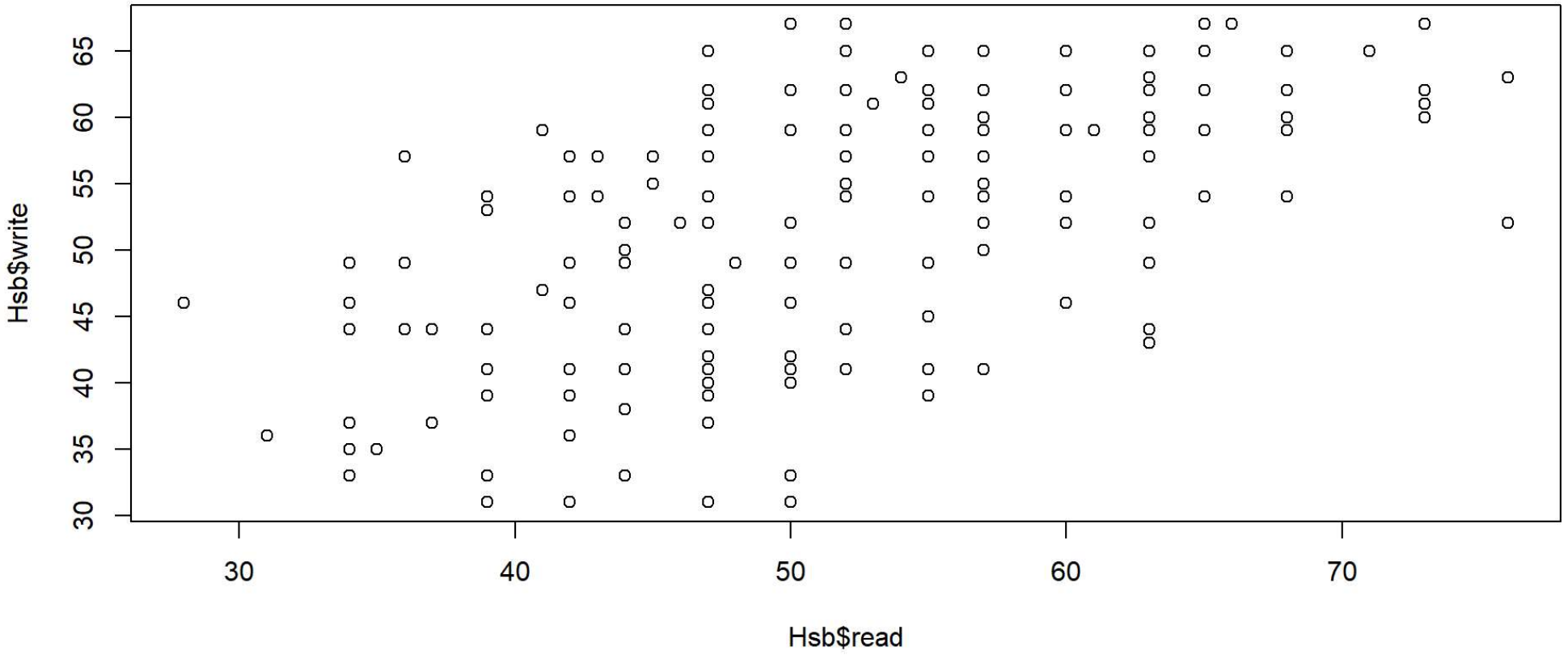
- Relation/correlation shows that if X increases, Y will increase or decrease, depending on the relation is positive or negative correlated
- Causality means that because of X, so we have Y
  - we know which variable happens first, then we have the outcome
- For example, return to our proposed relation: *"how far you live to the downtown and your income"*
  - it is difficult to know which variable causes which variable
  - e.g., maybe you're rich so you live in downtown; or because you're living in downtown so you find a better job; or because you was born in a high-class family so you are not only live in downtown but also have a good-paid

# Research question

- If `write` and `read` scores are correlated?

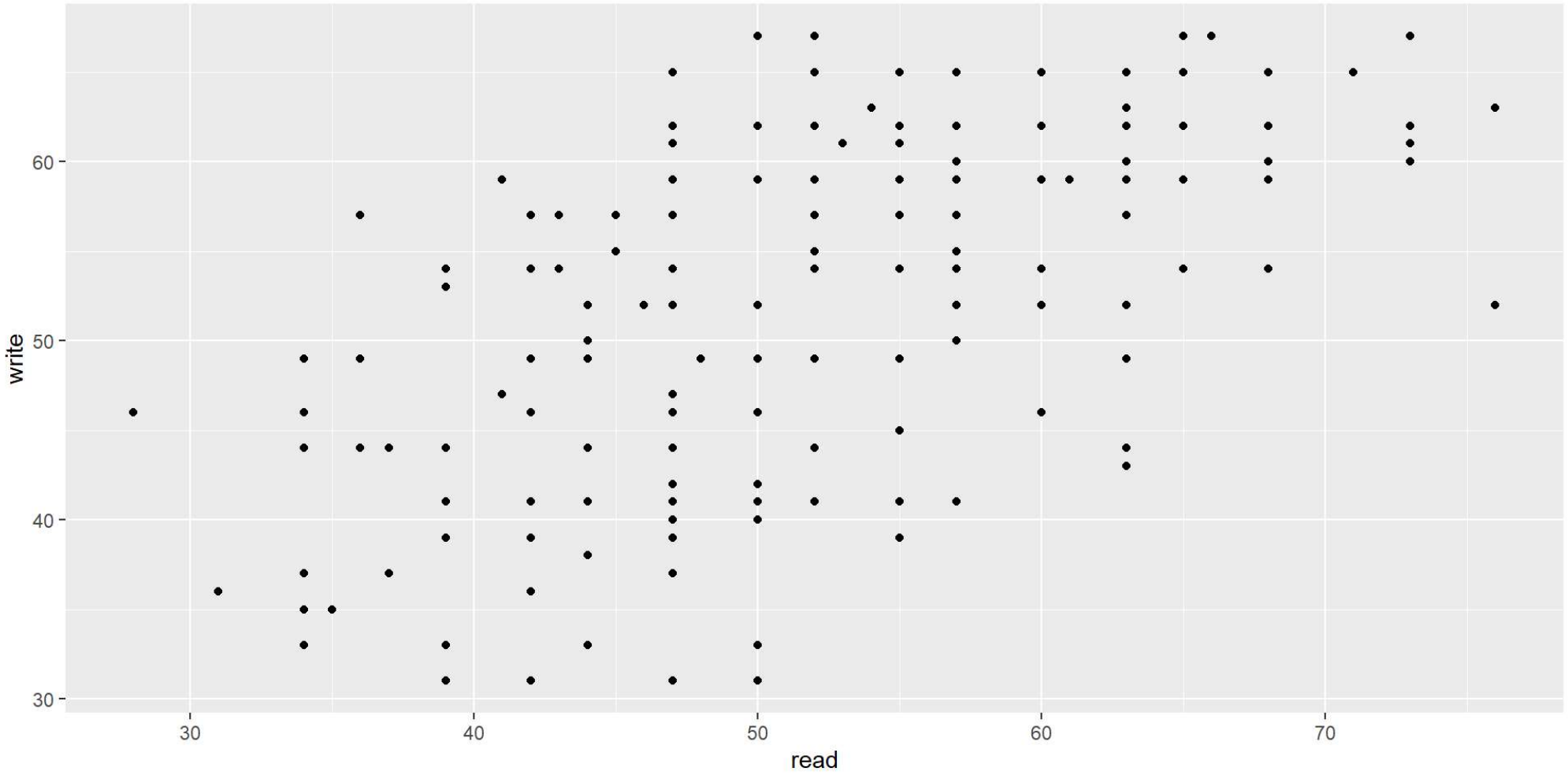
# Scatter plot

```
1 plot(x = Hsb$read, y = Hsb$write)
```



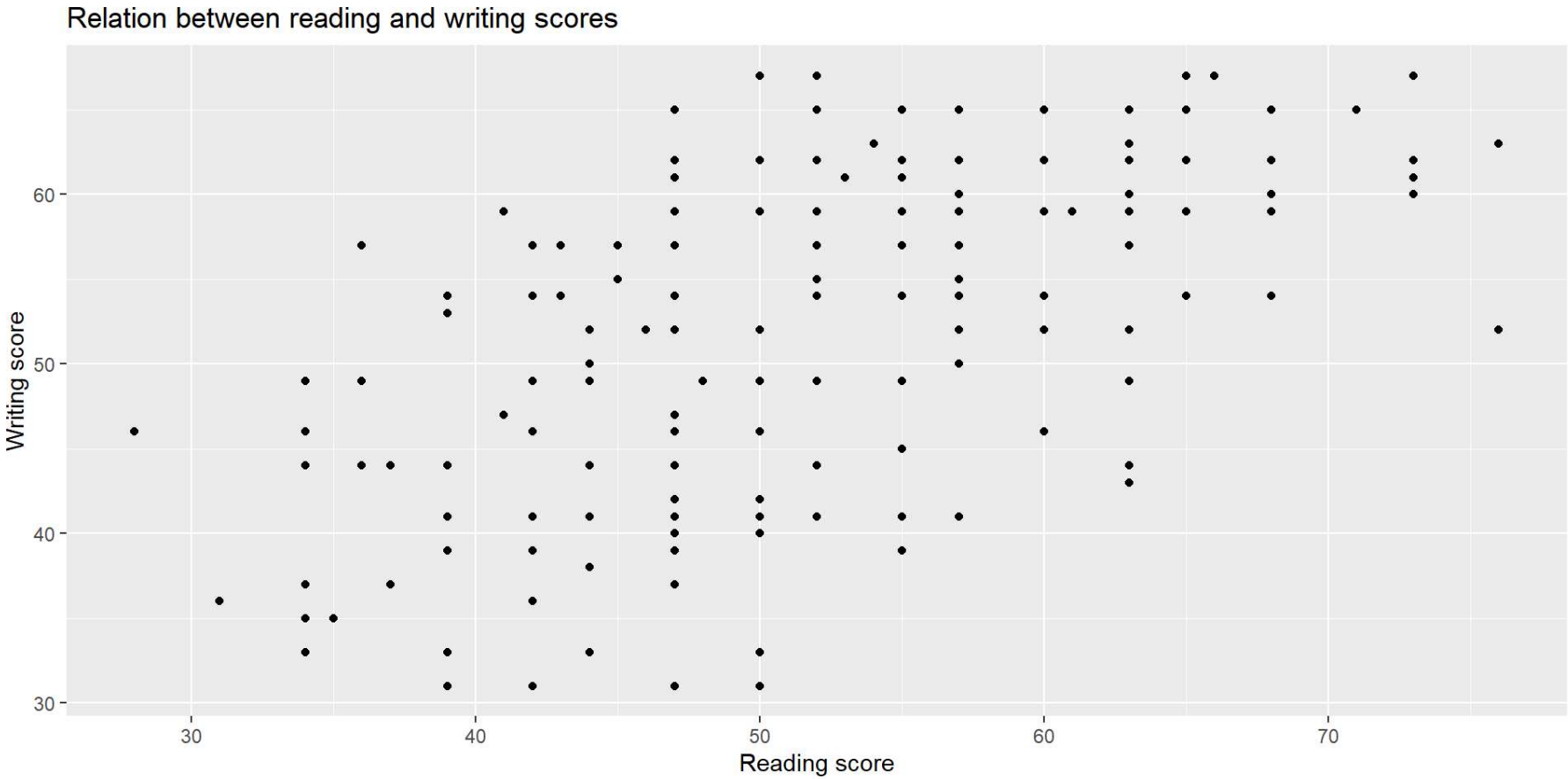
# More beautiful plot: using ggplot

```
1 ggplot(Hsb, aes(x=read, y=write)) + geom_point()
```



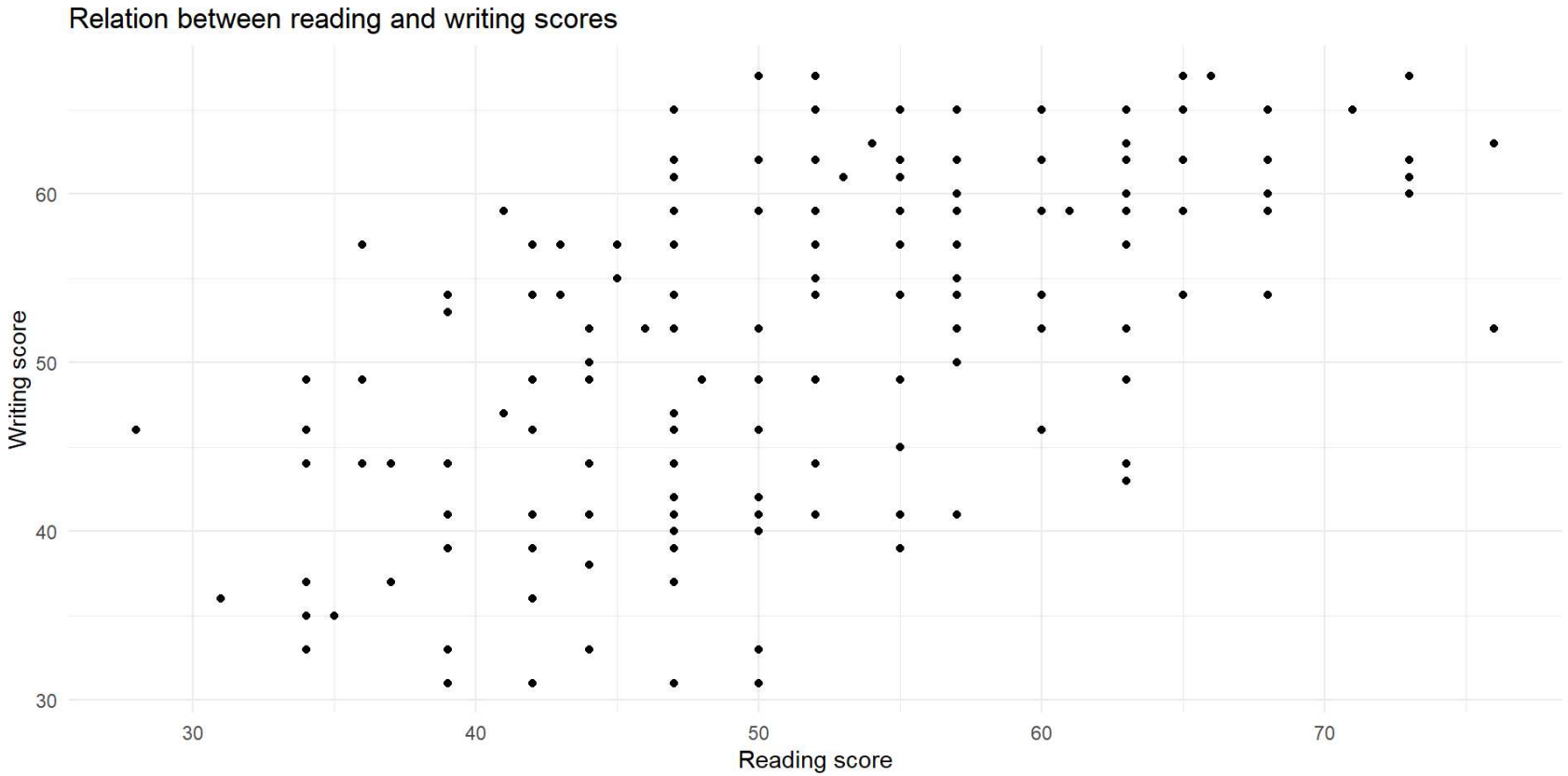
# Add labels

```
1 ggplot(Hsb, aes(x=read, y=write)) + geom_point() +
2   xlab("Reading score") + ylab("Writing score") +
3   labs(title = "Relation between reading and writing scores")
```



# Change the theme of the plot

```
1 ggplot(Hsb, aes(x=read, y=write)) + geom_point() +
2   xlab("Reading score") + ylab("Writing score") +
3   labs(title = "Relation between reading and writing scores") +
4   theme_minimal()
```



# To save the plot to file

```
1 ggsave("path_to_file.png") # I WILL NOT RUN, WILL DEMO IN CLASS LAT
```

# Correlation

```
1 cor(Hsb$read, Hsb$write)
```

```
[1] 0.5967765
```

## Test significance of the correlation:

```
1 cor.test(Hsb$read, Hsb$write)
```

```
    Pearson's product-moment correlation

data:  Hsb$read and Hsb$write
t = 10.465, df = 198, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.4993831 0.6792753
sample estimates:
      cor
0.5967765
```

# Regression

- In addition to correlation, we can run a regression between X and Y
- What is regression?
  - We use OLS to draw a line that show the relation between X and Y
  - There are so many possible lines that can draw thru the scatter plot
  - OLS method chooses the line that minimize the squared errors (a bit technical here, let me explain more!)

# Fit regression

```r
ols_reg_fit = lm(formula = write ~ read, data = Hsb)
summary(ols_reg_fit)
```

```
Call:
lm(formula = write ~ read, data = Hsb)

Residuals:
     Min       1Q   Median       3Q      Max 
-20.5447  -5.1225   0.6451   6.3259  15.4553 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 23.95944    2.80574   8.539 3.55e-15 ***
read         0.55171    0.05272  10.465  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.625 on 198 degrees of freedom
```

# Discussion

# Extension 1: More independent variables

- More variables in the right-hand side:
  - Why we put more variables to the regression?
  - E.g., Does gender affect the write score? Why we don’t put it to consideration?

# R code example

```r
ols_reg_fit = lm(formula = write ~ read + female, data = Hsb)
summary(ols_reg_fit)
```

```
Call:
lm(formula = write ~ read + female, data = Hsb)

Residuals:
    Min      1Q  Median      3Q     Max
-17.523  -5.658   0.168   5.043  15.175

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 20.22837    2.71376   7.454 2.80e-12 ***
read         0.56589    0.04938  11.459  < 2e-16 ***
female       5.48689    1.01426   5.410 1.82e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

# Discuss

- `read` coefficient changed!
  - larger or smaller?
  - why? because we controlled for gender!
- Similarly, we can control as nearly all variables we think/find it important
- Which variables we need to control?
  - Ask an expert
  - Read the literature

# Extension 2: transformed variables in regression

- Sometimes, we want to transform variables before putting them to the regression
- For example, we may want to take log of scores before regressions

```
# transform
write_log = log(Hsb$write)
read_log = log(Hsb$read)

# fit
ols_reg_fit = lm(formula = write_log ~ read_log)
summary(ols_reg_fit)
```

```
Call:
lm(formula = write_log ~ read_log)
```

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.50072 -0.08877  0.02909  0.11874  0.29463

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.71628    0.21963   7.814 3.18e-13 ***
read_log     0.56708    0.05573  10.176  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

# A quicker method: using `I()`

```
1 ols_reg_fit = lm(formula = I(log(write)) ~ I(log(read)), data = Hsb
2 summary(ols_reg_fit)
```

```
Call:
lm(formula = I(log(write)) ~ I(log(read)), data = Hsb)

Residuals:
     Min       1Q   Median       3Q      Max
-0.50072 -0.08877  0.02909  0.11874  0.29463

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.71628    0.21963   7.814 3.18e-13 ***
I(log(read))  0.56708    0.05573  10.176  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1572 on 198 degrees of freedom
```

# Another quiz

- Can you run a regression between `write` and `read` and the squares of `read`?

# Extension 3: Interaction between X variables

- For example: we want to regress `write` on `read`, `female`, and the interaction between these two
- We can do manually, or using the below code:

```
1 ols_reg_fit = lm(formula = write ~ read*female, data = Hsb)
2 summary(ols_reg_fit)
```

```
Call:
lm(formula = write ~ read * female, data = Hsb)

Residuals:
     Min       1Q   Median       3Q      Max
-17.3247  -5.1255  -0.1181   4.9666  15.5834

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
```

```
(Intercept) 16.52388    3.84511   4.297 2.72e-05 ***
read         0.63602    0.07141   8.907 3.59e-16 ***
female      12.49063    5.25927   2.375   0.0185 *
read:female -0.13390    0.09867  -1.357   0.1763
---
```

# Last words for this lecture

- Oops, you may be too tired at this step
- But not yet finished, we need to learn more about assumption diagnostics
- We also learn how to `tidy` the regression results in the next lecture