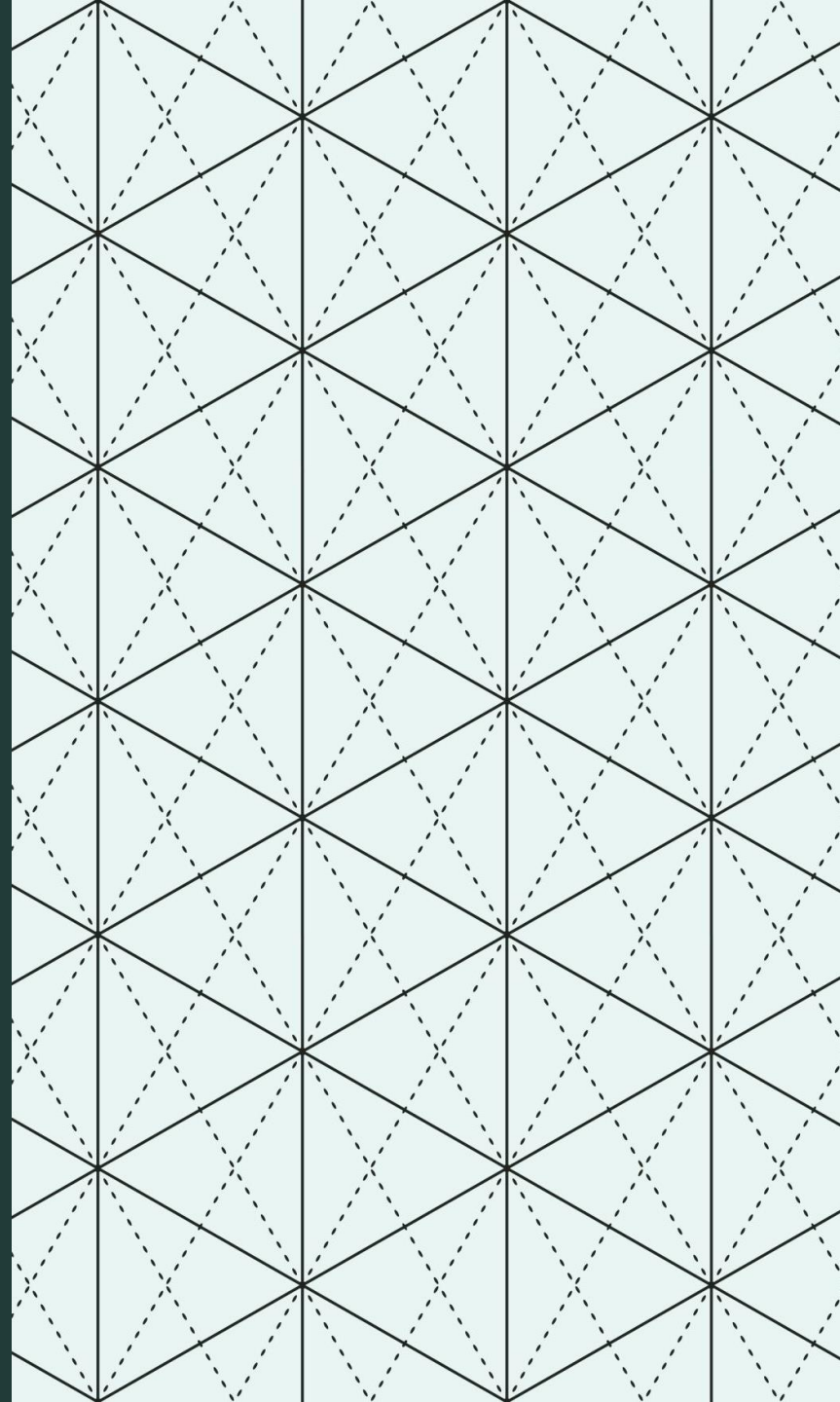
# WELCOME TO PSY 653 LAB!

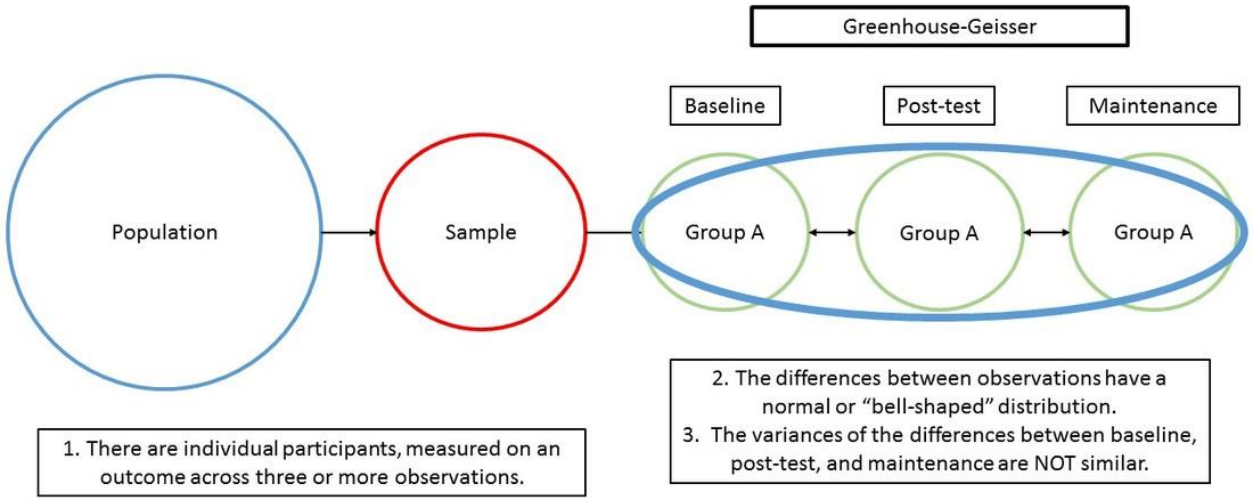
MODULE 06: REPEATED MEASURES AND MIXED DESIGNS

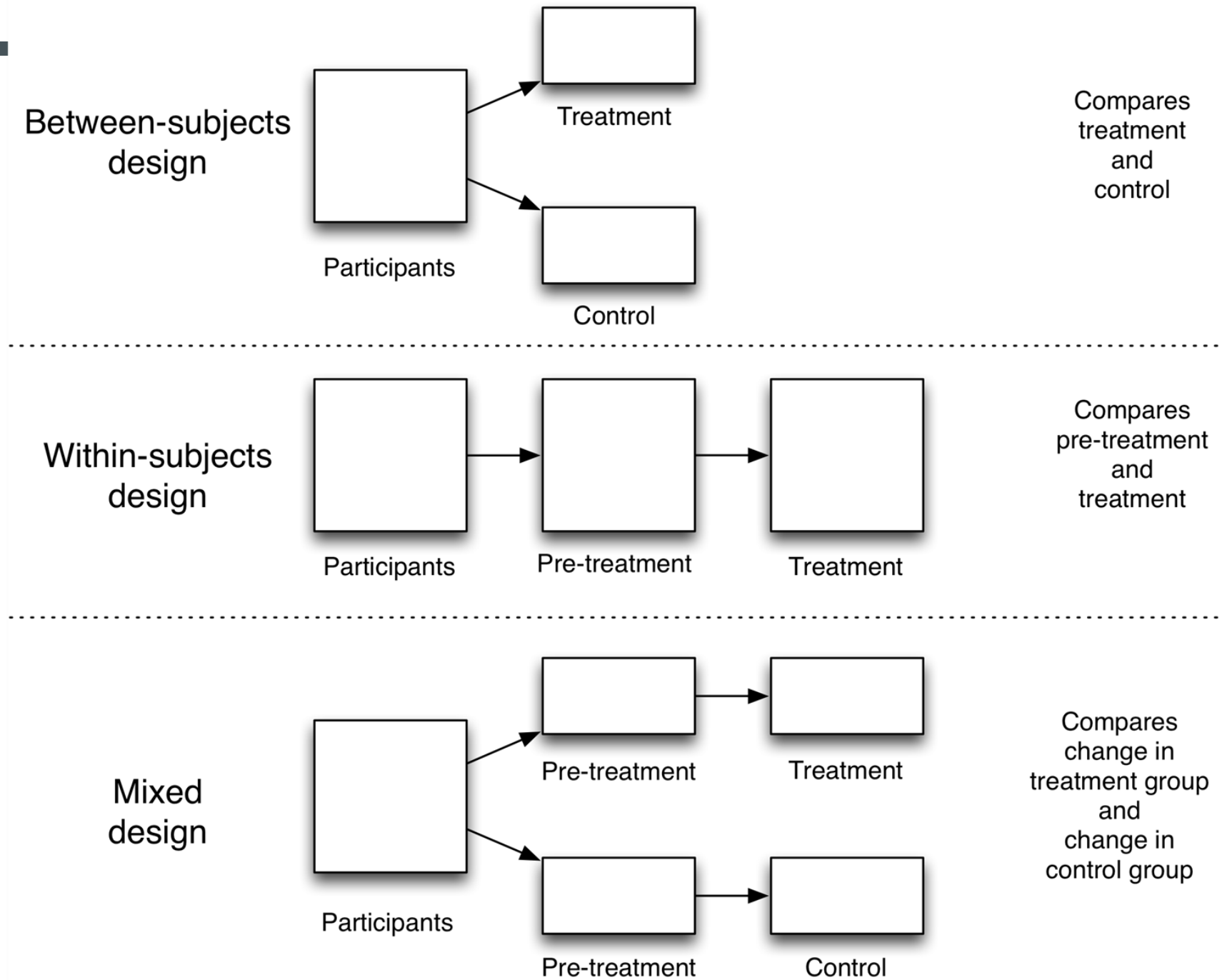


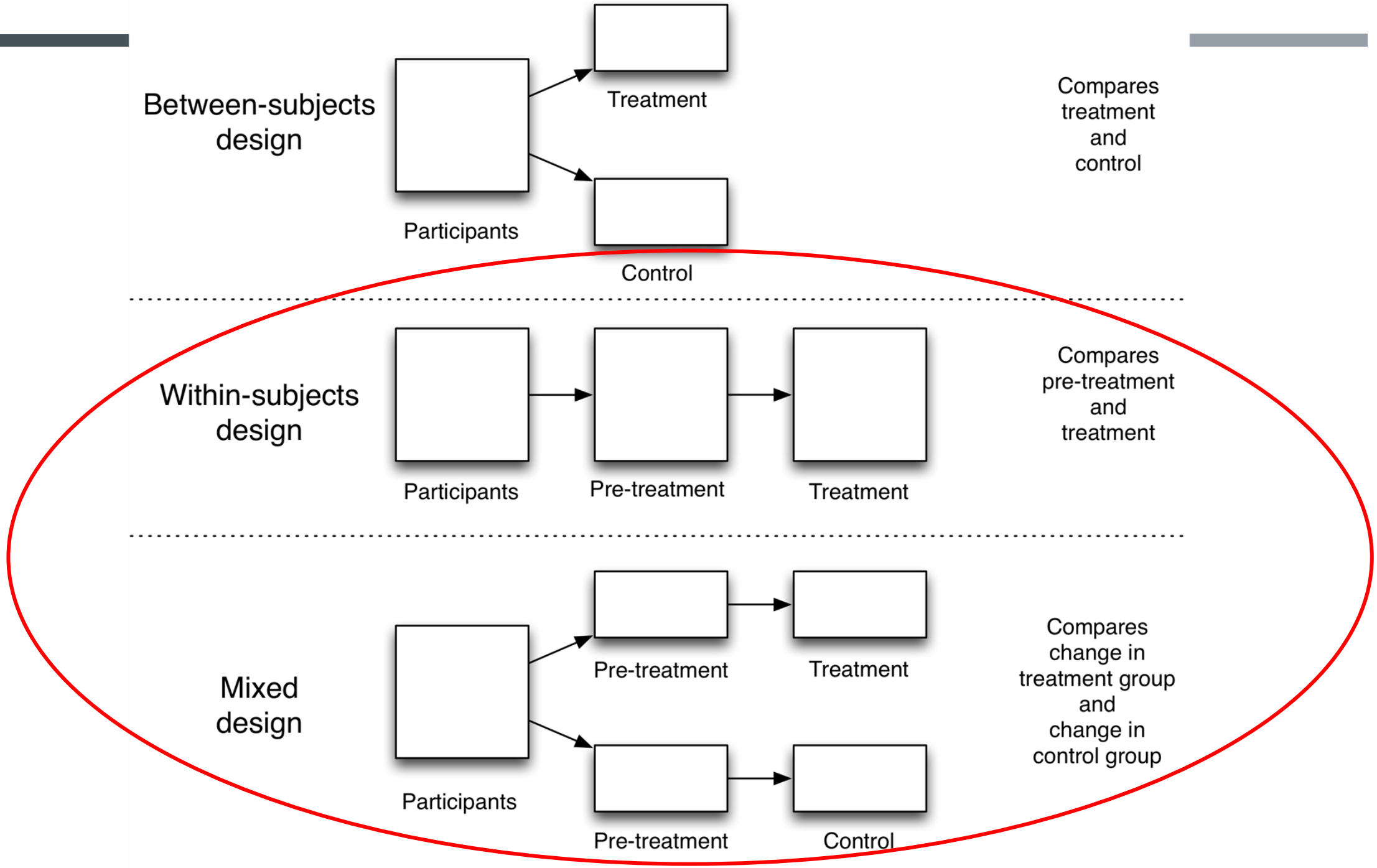
*Thanks to Gemma Wallace for her help with these slides

# KEY TERMS

- **Repeated Measures**
  - When subjects participate in all conditions of an experiment or provide data at multiple timepoints
- **Sphericity**
  - Equality of variances of the *differences* between treatment levels




Between-subjects design
Participants
Treatment
Control
Compares treatment and control
Within-subjects design
Participants
Pre-treatment
Treatment
Compares pre-treatment and treatment
Mixed design
Participants
Pre-treatment
Treatment
Pre-treatment
Control
Compares change in treatment group and change in control group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Compares change in treatment group and change in control group

# CLASS EXAMPLE

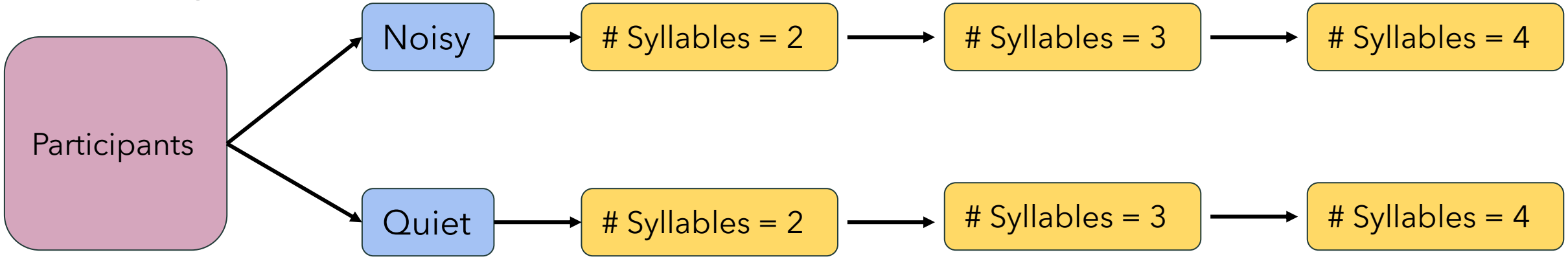
A researcher is interested in the length of time it takes to say 2 syllable, 3 syllable, and 4 syllable words. She first times how long it takes each participant to say the 2 syllable word, then the 3 syllable word, then the 4 syllable word. However, half the participants are put in a condition in which there is a distracting noise in the background. She is interested if there is a difference between the control condition and the noise condition.

Source: Henderson, L., Coltheart, M., & Woodhouse, D. (1973). Failure to find a syllabic effect in number naming. Memory & Cognition, 1(3), 304-306. Retrieved from: http://users.stat.ufl.edu/~winner/data/

# OUR VARIABLES AND RESEARCH DESIGN

- Noise Condition = between-subjects factor
  - Every participant is only exposed to one condition, either control or noisy
- # of syllables = within-subjects factor
  - Every participant reads words of all three syllable lengths
- Length of time to say each word = outcome variable

Mixed design



# CREATE A NEW R-PROJECT AND R-NOTEBOOK!

Download the “syllables.csv” file from Canvas and save it into your R-project file

# LOAD LIBRARIES

# Load libraries

```{r}
install.packages("ez")

library(tidyverse)
library(ez)
library(psych)
```

# READ IN THE DATA

```
# Read in data
```{r}
syl <- read_csv("syllables.csv")
```
```

```
Parsed with column specification:
cols(
  ID = col_double(),
  length = col_double(),
  cond = col_double(),
  time = col_double()
)
```

- ID = subject id
- length = # of syllables in word (2, 3, or 4)
- cond = condition (0 = control, 1 = noise condition)
- time = milliseconds it took to say the word (outcome variable)

# DESCRIBE THE DATASET

```r
describe(syl)
```

| | vars <dbl> | n <dbl> | mean <dbl> | sd <dbl> | median <dbl> | trimmed <dbl> | mad <dbl> | min <dbl> | max <dbl> |
|---|---|---|---|---|---|---|---|---|---|
| ID | 1 | 48 | 8.50 | 4.66 | 8.5 | 8.5 | 5.93 | 1 | 16 |
| length | 2 | 48 | 3.00 | 0.83 | 3.0 | 3.0 | 1.48 | 2 | 4 |
| cond | 3 | 48 | 0.50 | 0.51 | 0.5 | 0.5 | 0.74 | 0 | 1 |
| time | 4 | 48 | 519.67 | 54.52 | 519.0 | 519.3 | 50.41 | 402 | 641 |

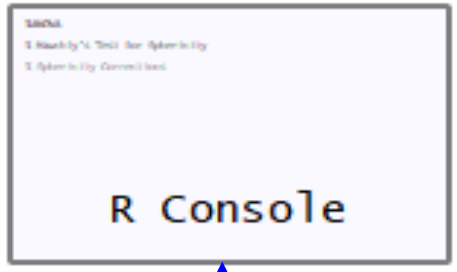
4 rows | 1-10 of 13 columns

# FACTOR THE PREDICTOR VARIABLES

```
# Factor variables
```{r}
syl <- mutate(syl,
              ID.f     = as.factor(ID),
              cond.f   = factor(cond,
                                levels = c(0,1),
                                labels = c("Quiet", "Noisy")),
              length.f = factor(length,
                                levels = c(2,3,4),
                                labels = c("2 syl", "3 syl", "4 syl"))
              )
```
```

*Note: ezANOVA() (The main function we'll be using today) will do this automatically, but it's nice to remove the warning message and it looks nicer!

# THE ezANOVA() FUNCTION

```
ezANOVA(data = dataframe,
  dv = outcome_variable,
  wid = variable_that_identifies_participants,
  within = repeated_measures_predictors,
  between = between_group_predictors,
  detailed = TRUE,
  type = 3)
```

If there are multiple predictor variables for each category, use a ".", parentheses, and separate them with a comma e.g., .(x,y). Use ?ezANOVA for more information

# **ANALYSES 1**: RESEARCH QUESTION

Does length of time to read each word significantly differ by word syllable length? (We are ignoring Condition for analyses 1)

# ANALYSIS 1: RUN A REPEATED MEASURES ANOVA (IGNORING CONDITION FOR NOW)

```
32 # Repeated measures ANOVA
33 ```{r}
34 ezANOVA(
35         data = syl,
36         dv = time,
37         wid = ID.f,
38         within = length.f,
39         detailed = TRUE,
40         type = 3
41         )
42 ```
```

```
# Repeated measures ANOVA
```{r}
ezANOVA(
        data = syl,
        dv = time,
        wid = ID.f,
        within = length.f,
        detailed = TRUE,
        type = 3
        )
```
```

- data = dataset
- dv = dependent variable
- wid = ID grouping variable (factored)
- within = within subject variable (factored)
- “detailed = TRUE” indicates we want detailed output
- “type = 3” indicates we would like it to perform a type 3 ANOVA

# 4 WINDOWS WILL BE OUTPUTTED!




data.frame
2 x 9

data.frame
1 x 4

data.frame
1 x 7

```
$ANOVA

$`Mauchly's Test for Sphericity`

$`Sphericity Corrections`
```

R console
(Errors will be reported here)

ANOVA table

Sphericity test

Greenhouse-Geisser & Huynh-Feldt corrections (Use if spericity is violated)

# FIRST, CHECK IF SPHERICITY IS VIOLATED

Sphericity = the variances of the differences between all possible pairs of within-subject conditions (i.e., levels of the categorical predictor) are equal


data.frame
2 x 9

data.frame
1 x 4

data.frame
1 x 7

| | Effect <chr> | W <dbl> | p <dbl> | p<.05 <chr> |
|---|---|---|---|---|
| 2 | length | 0.8402584 | 0.2957264 | |

1 row

A *non-significant* *p* value (i.e., >0.05) means that the condition of sphericity has been met. We do NOT need to use the Greenhouse-Geisser & Huynh-Feldt corrections (Window 4)

# CHECK IF SPHERICITY IS VIOLATED


data.frame
2 x 9

**data.frame**
1 x 4

data.frame
1 x 7

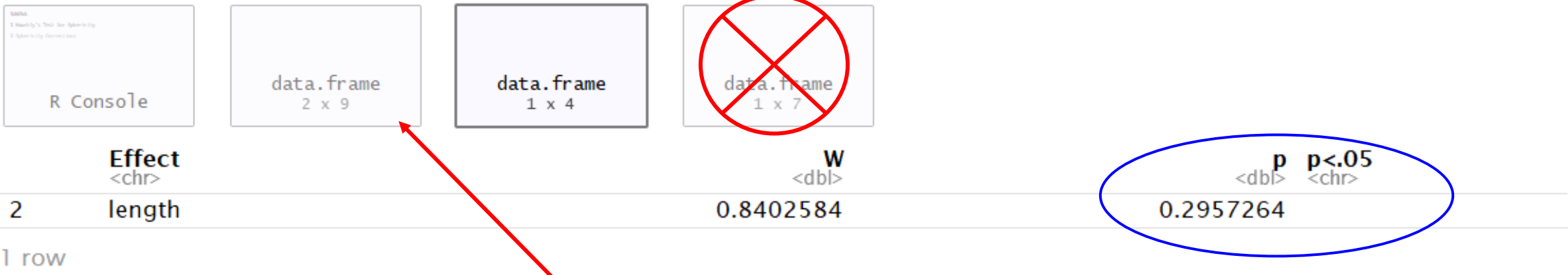
| | Effect <chr> | W <dbl> | p <dbl> | p<.05 <chr> |
|---|---|---|---|---|
| 2 | length | 0.8402584 | 0.2957264 | |

1 row

Was it violated?

# CHECK IF SPHERICITY IS VIOLATED

ANOVA table




| | Effect <chr> | W <dbl> | p <dbl> | p<.05 <chr> |
|---|---|---|---|---|
| 2 | length | 0.8402584 | 0.2957264 | |

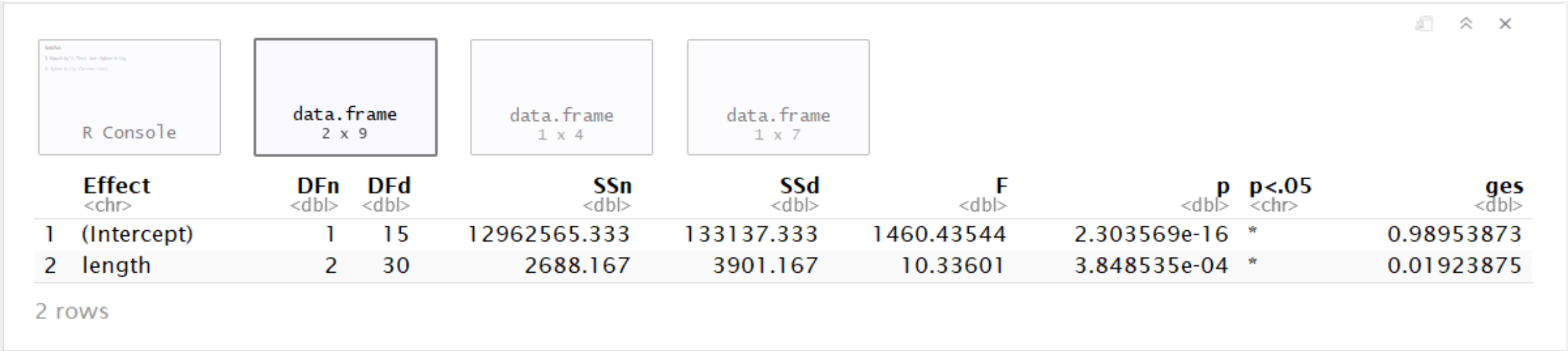
1 row

Was it violated?

**NO!**

(therefore we don't need to deal with window 4)

# NEXT, VIEW THE ANOVA TABLE (SINCE SPHERICITY WASN'T VIOLATED)




| | Effect <chr> | DFn <dbl> | DFd <dbl> | SSn <dbl> | SSd <dbl> | F <dbl> | p <dbl> | p<.05 <chr> | ges <dbl> |
|---|---|---|---|---|---|---|---|---|---|
| 1 | (Intercept) | 1 | 15 | 12962565.333 | 133137.333 | 1460.43544 | 2.303569e-16 | * | 0.98953873 |
| 2 | length | 2 | 30 | 2688.167 | 3901.167 | 10.33601 | 3.848535e-04 | * | 0.01923875 |

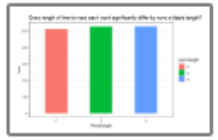
2 rows

### Visualize the effect

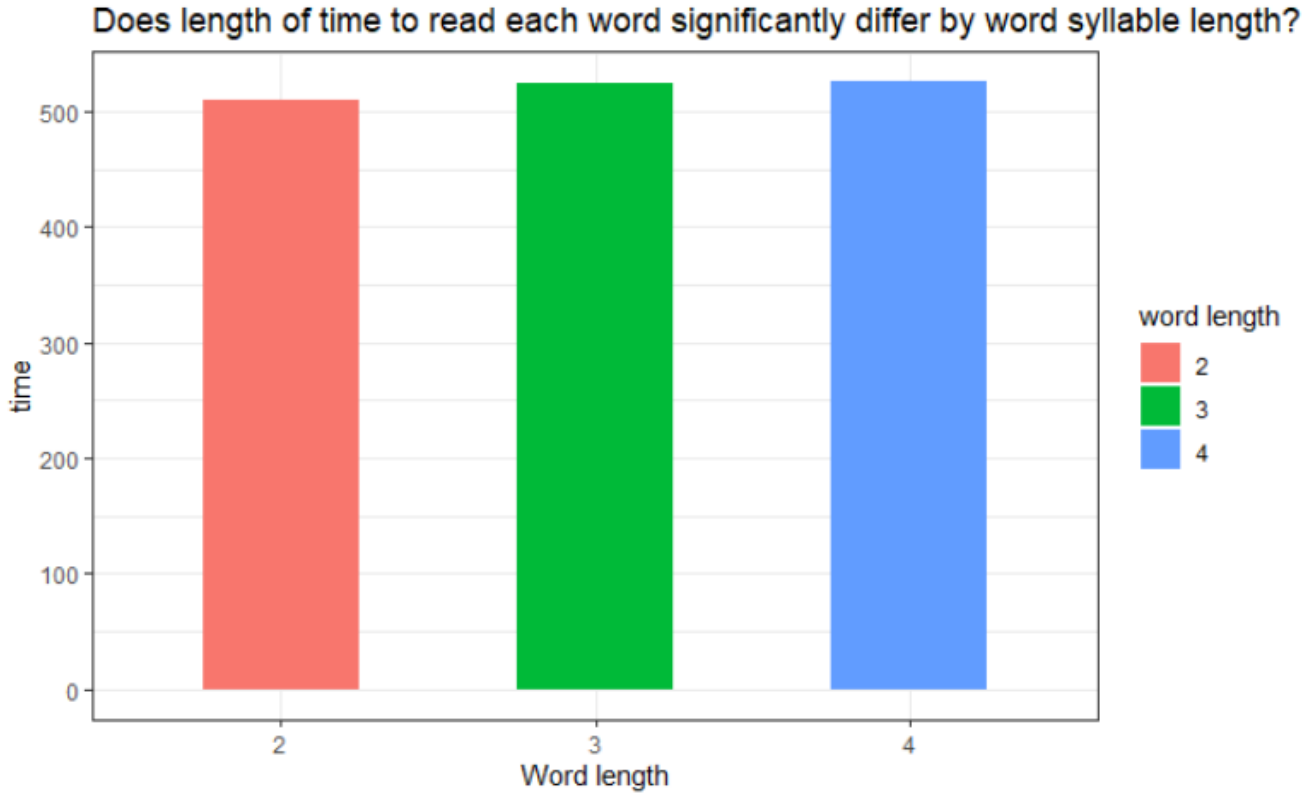
```{r}
syl_sum <- group_by(syl, length.f)
syl_sum <- summarise(syl_sum, time = mean(time))
syl_sum <- ungroup(syl_sum)

ggplot(syl_sum, aes(x = length.f, y = time, group = length.f, fill = length.f)) +
  geom_col(width = .5) +
  theme_bw() +
  labs(title = "Does length of time to read each word significantly differ by word syllable length?", fill = "word length",
       x = "Word length")

```



R Console



# **ANALYSIS 2**:
# RUN A MIXED EFFECTS ANOVA TO EVALUATE EFFECTS OF BOTH # OF SYLLABLES AND NOISE CONDITION ON TIME

Does length of time to read each word significantly differ by word syllable length AND by condition?

# ANALYSIS 2: RUN A MIXED EFFECTS ANOVA TO EVALUATE EFFECTS OF BOTH # OF SYLLABLES AND NOISE CONDITION ON TIME

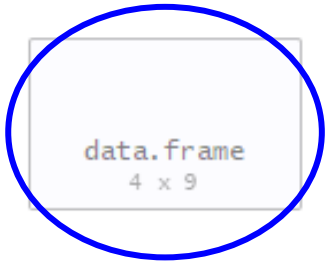
```
## Mixed design
```{r}
ezANOVA(
        data=syl,
        dv=time,
        wid=ID,
        within= length,
        between = cond,
        detailed=TRUE,
        type = 3
        )
```
```

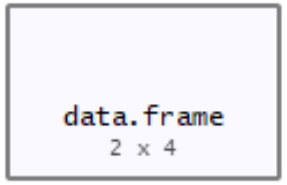
# FIRST, CHECK IF SPHERICITY WAS VIOLATED


| | Effect <chr> | W <dbl> | p <dbl> | p<.05 <chr> |
|---|---|---|---|---|
| 3 | length | 0.8953253 | 0.4873887 | |
| 4 | cond:length | 0.8953253 | 0.4873887 | |

2 rows

# FIRST, CHECK IF SPHERICITY WAS VIOLATED



| | Effect <chr> | W <dbl> | p <dbl> | p<.05 <chr> |
|---|---|---|---|---|
| 3 | length | 0.8953253 | 0.4873887 | |
| 4 | cond:length | 0.8953253 | 0.4873887 | |

2 rows

Sphereicity was <u>NOT</u> violated (p > .05)

# NEXT, VIEW THE ANOVA TABLE (SINCE SPHERICITY WASN'T VIOLATED)


data.frame
4 x 9

data.frame
2 x 4

data.frame
2 x 7

| | Effect <chr> | DFn <dbl> | DFd <dbl> | SSn <dbl> | SSd <dbl> | F <dbl> | p <dbl> | p<.05 <chr> | ges <dbl> |
|---|---|---|---|---|---|---|---|---|---|
| 1 | (Intercept) | 1 | 14 | 1.296257e+07 | 132976 | 1.364727e+03 | 2.342147e-15 | * | 0.989620054 |
| 2 | cond | 1 | 14 | 1.613333e+02 | 132976 | 1.698552e-02 | 8.981607e-01 | | 0.001185200 |
| 3 | length | 2 | 28 | 2.688167e+03 | 2986 | 1.260359e+01 | 1.249189e-04 | * | 0.019388124 |
| 4 | cond:length | 2 | 28 | 9.151667e+02 | 2986 | 4.290802e+00 | 2.368832e-02 | * | 0.006686043 |

4 rows

SSd = an error term: the amount of unexplained variance across the conditions of the within-subjects variable

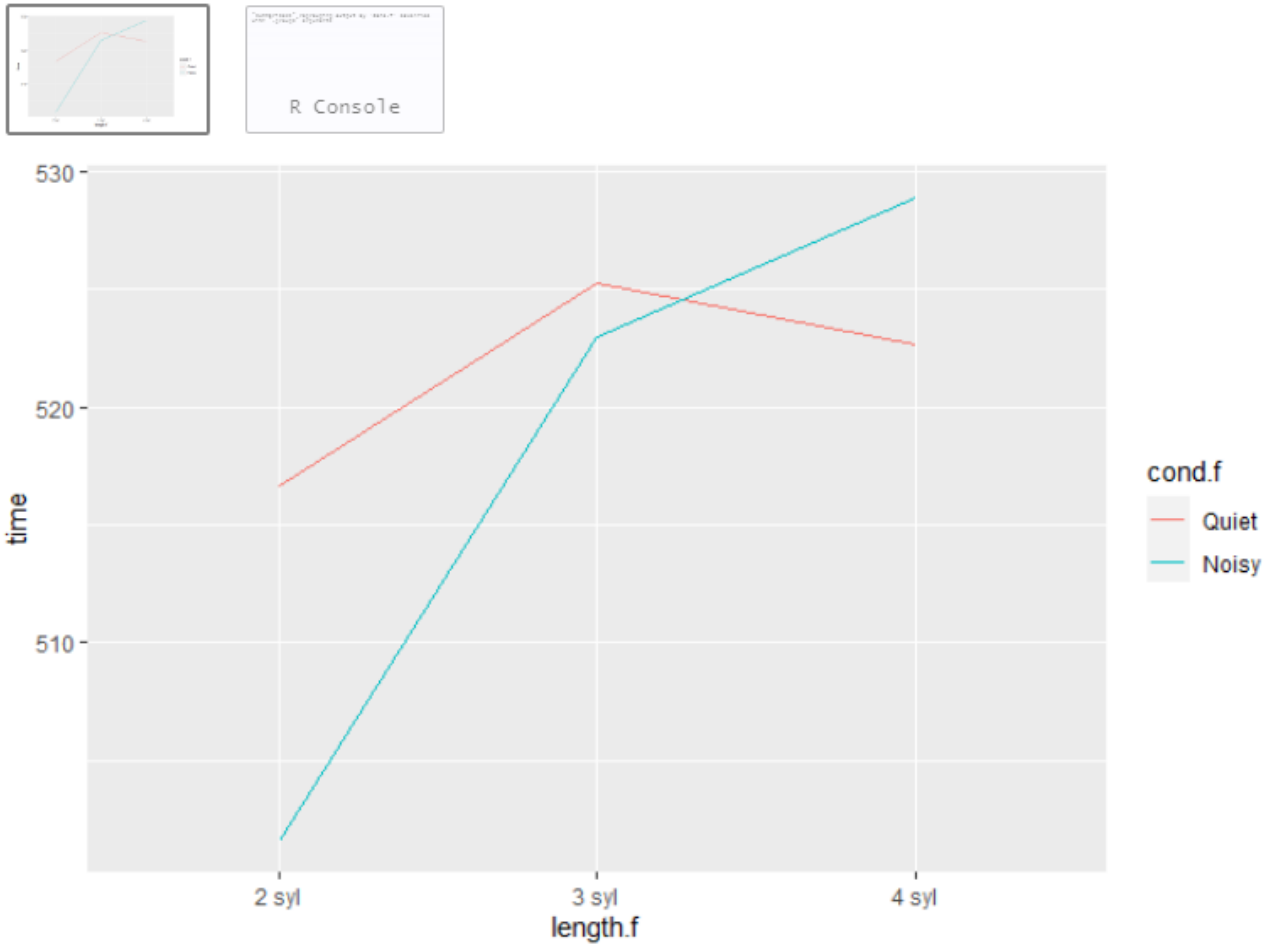
```r
# Visualize the effect
```{r}


syl_sum <- group_by(syl, cond.f, length.f)
syl_sum <- summarise(syl_sum, time = mean(time))
syl_sum <- ungroup(syl_sum)



ggplot(syl_sum, aes(x = length.f, y = time, color = cond.f)) +
  geom_line(aes(group = cond.f))


```
```




# VISUALIZE THE EFFECTS OF SYLLABLE LENGTH AND NOISE CONDITION ON TIME TO SAY EACH WORD

# WHAT SHOULD YOU DO IF THE SPHERICITY ASSUMPTION IS VIOLATED?

We didn't violate the assumption in this demo activity, but if we had:

- Use the output from Window 4 and apply a correction to the model F Ratio,and then use that value in your model interpretations.