

Homework Feedback (1)

- Avoid “statistical significant effect”, “The difference is significant”
- Model comparison:
“The full model is significant, $F(1,...) = ..., p < 0.05$ ”
The F test is comparing two models 
- Which of the models nest within each other?
 - Model 1: $\hat{Y} = \beta_0 + \beta_1 X_1$
 - Model 2: $\hat{Y} = \beta_0 + \beta_2 X_2 + \beta_4 X_4$
 - Model 3: $\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$
 - A simpler model is nested within the more complex one *if* the more complicated model has all the elements the simpler one has

Homework Feedback (2)

- high/low correlation with the dv and with other predictors: you have to communicate what your criteria are ($r_{\text{predictor_dv}}=0.2$ and $r_{\text{predictors}}=0.5$)
 - because not everyone agrees with your rule of thumb
 - Same for outlier detection (3SD above or below the mean)
 - Same for VIF ($\text{VIF} > 10 \rightarrow$ cautious)
- FHWKHRS is the hours spent on doing homework per week; This predictor is negatively correlated with student's performance in school.

segradeq

$= 1.28 + 0.34 \times \text{seenjoy} + 0.15 \times \text{fcstds} - 0.04 \times \text{fhwkhrs}$

$- 0.03 \times \text{P1EDUC} + 0.2 \times \text{hdhealth}$

Less time spent on homework $\rightarrow$ better grades in school?

E21. How would you describe his/her work at school?

Variable Name : SEGRADEQ Label: E21. Description of school work
Position : 90-91
Format : N2.

Response	code	frequency	percent
1 Excellent	1	4,390	31.19%
2 Above average	2	4,612	32.77%
3 Average	3	3,825	27.18%
4 Below average	4	632	4.49%
5 Failing	5	64	0.45%

-1 Valid Skip E36. In an average week, how many hours does this child spend on homework outside of school?

Total

Variable Name : FHWKHRS Label: E36. Hours spent doing homework
Position : 160-161
Format : N2.

				weighted	we
Response	code	frequency	percent	frequency	f
	0-75	12,795	90.91%	48,262,006	

Goals in Multiple Regression

1. Test if a *linear* relationship between multiple predictor variables and the dependent variable
2. Search for the simplest (parsimonious) model that describes the relationship
 - Use the fewest predictors possible
3. Describe the linear relationship in mathematical form
 - That would help us make predictions with *new* data
 - The resulting mathematical equation should be interpretable

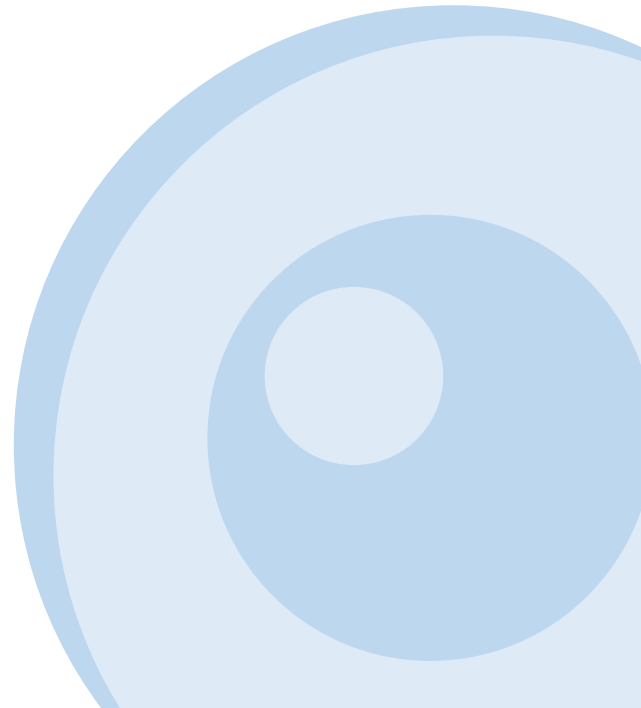


PSYC 193R:

Data Analysis & Visualization with R

Lecture 18: Two-way ANOVA 2

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Second Language (L2) Acquisition

It is believed that adults have more difficulties acquiring a second language (L2) compared to children.

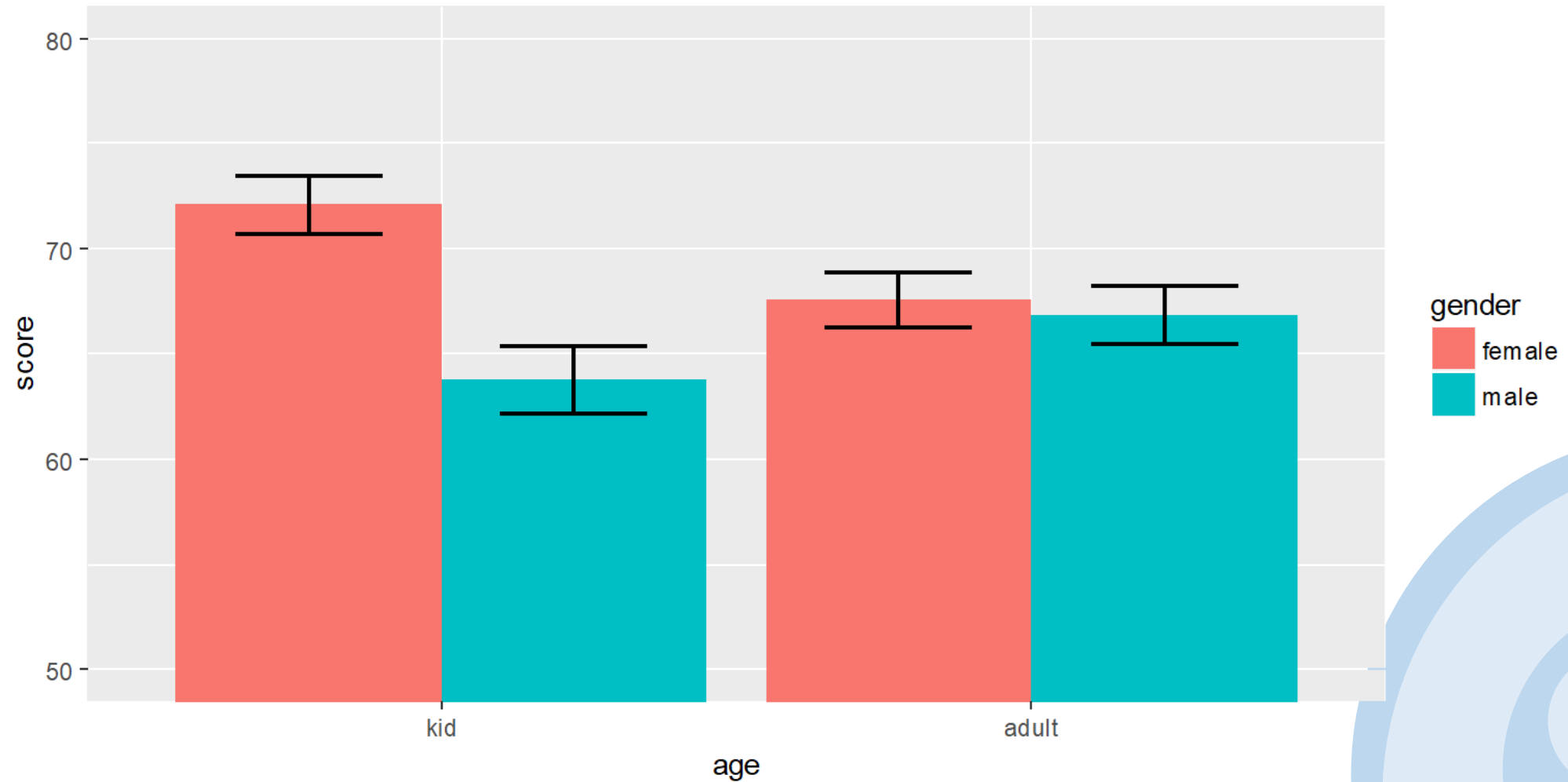
A group of language researchers at UC San Diego would like to examine the claim. In addition to **age**, they also wanted to study the effect of **gender**, which is also thought to contribute to L2 acquisition. The researchers recruited a group of English monolingual first graders, and a group of English monolingual undergraduates.

In a school year, these learners were given the same Cantonese 101 class administered by a group of experience teachers. Cantonese (a Chinese dialect) was chosen because it is very distinct from English, and its deep connections with Chinese literature. **Written and spoken language abilities** were assessed at the end of the course.

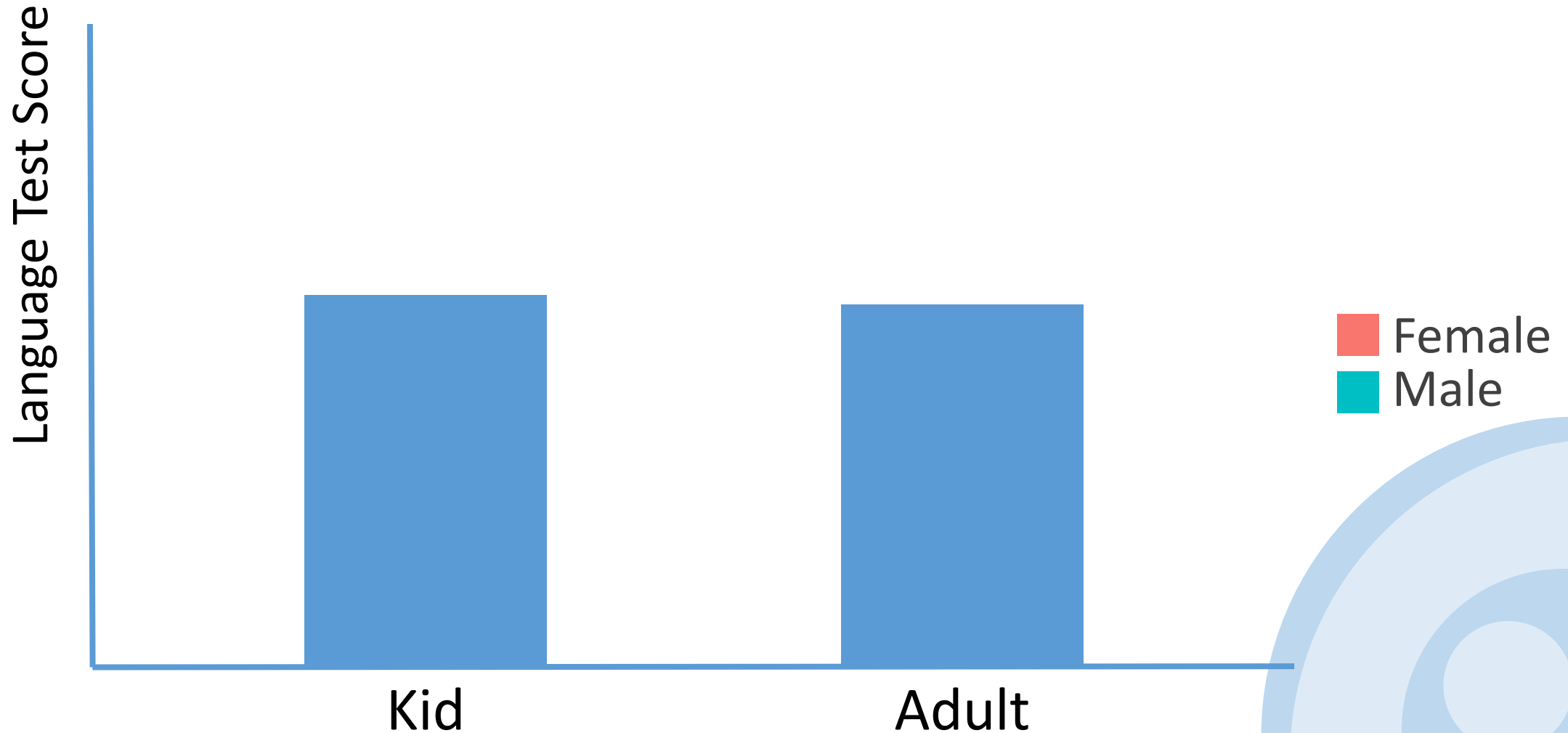


Combined

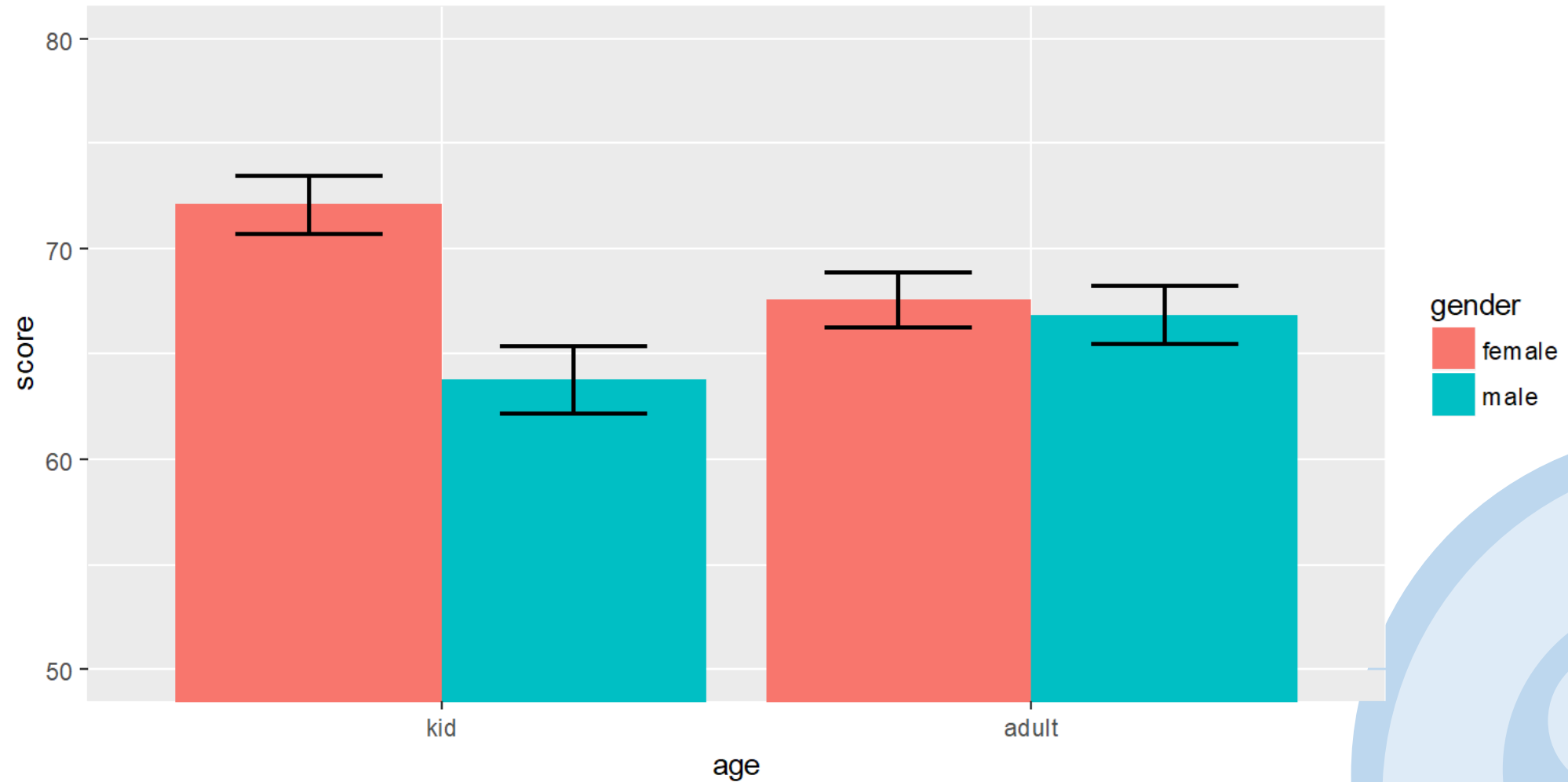
Main Effect / Interaction / Simple Effect



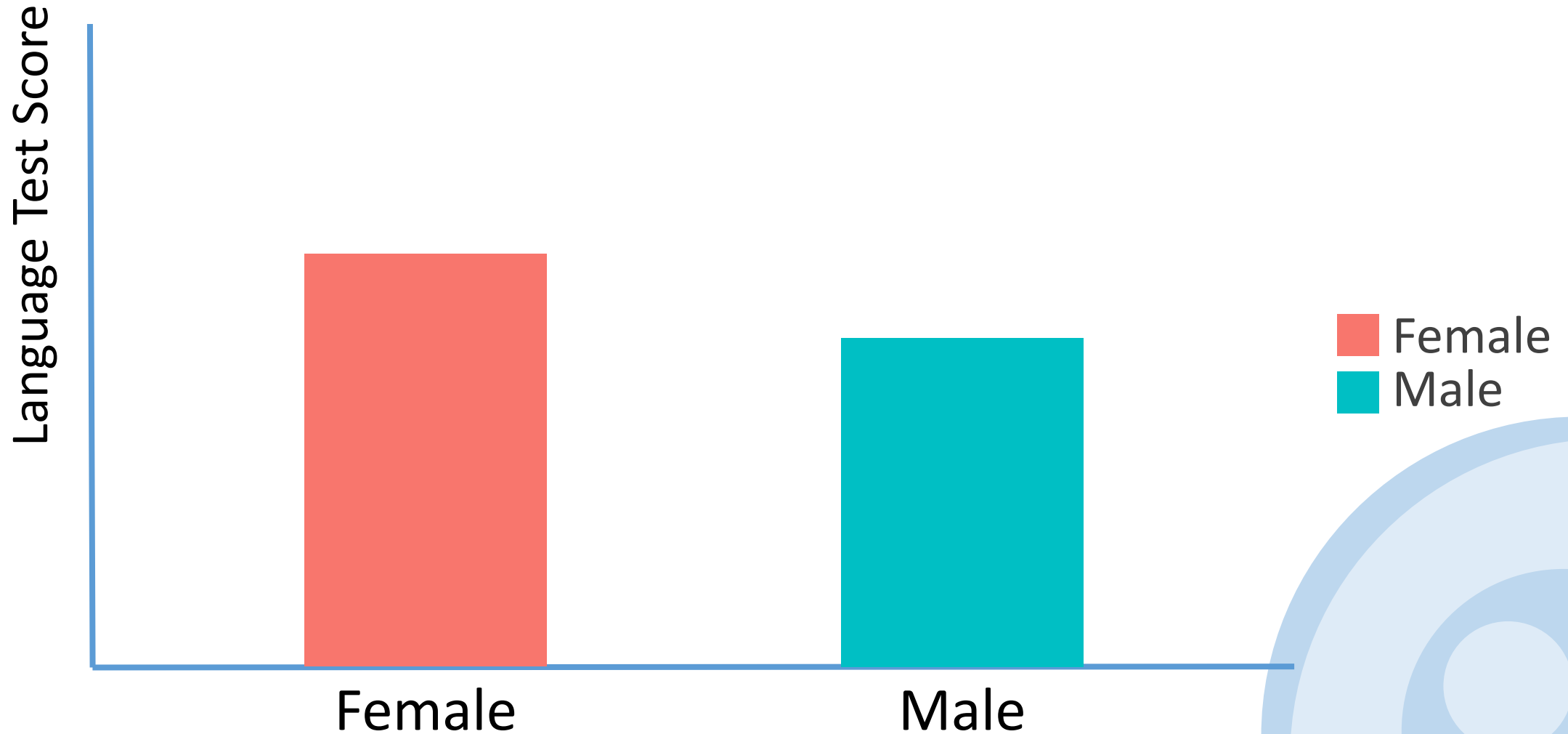
Main Effect / Interaction / Simple Effect



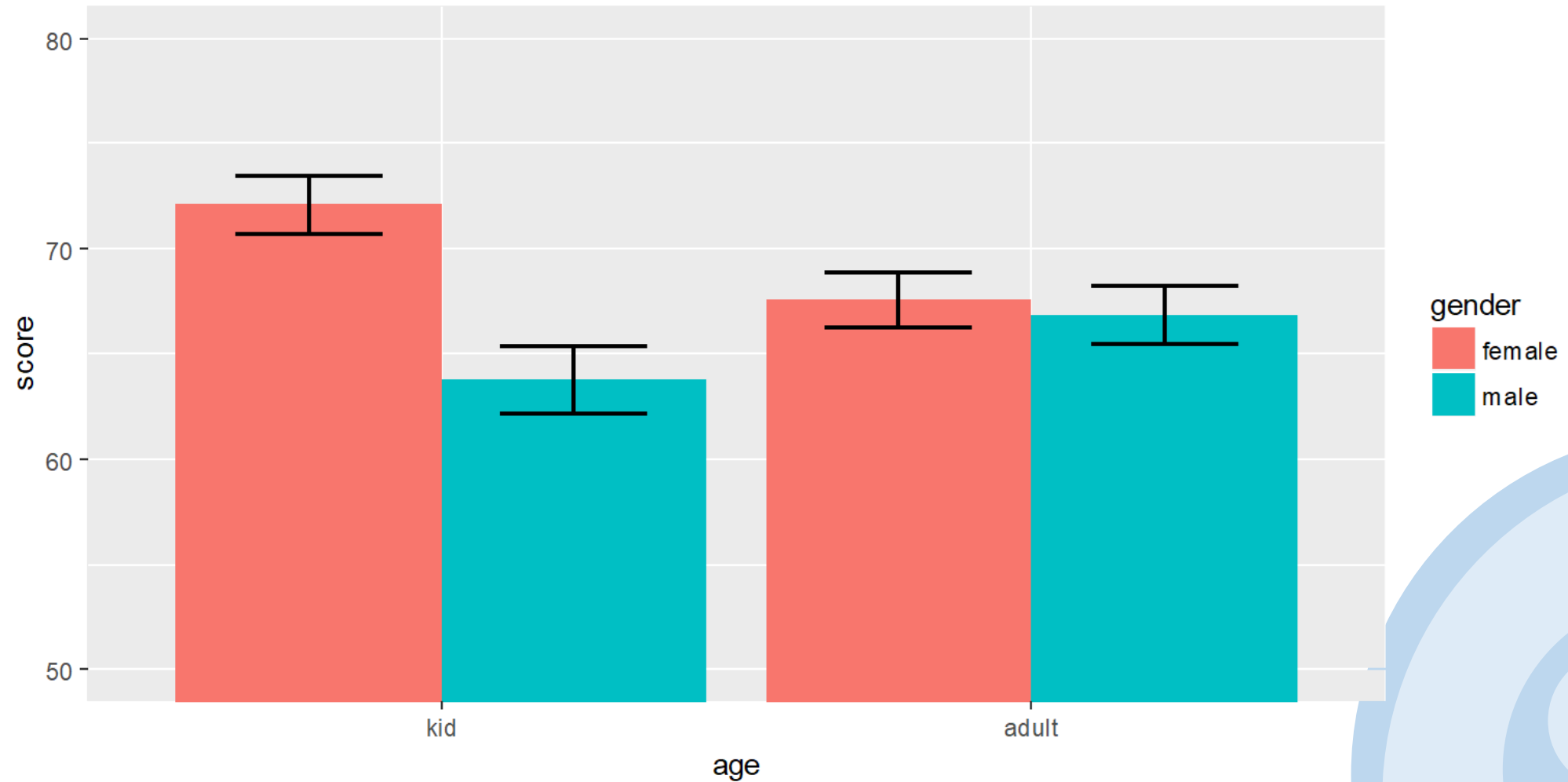
Main Effect / Interaction / Simple Effect



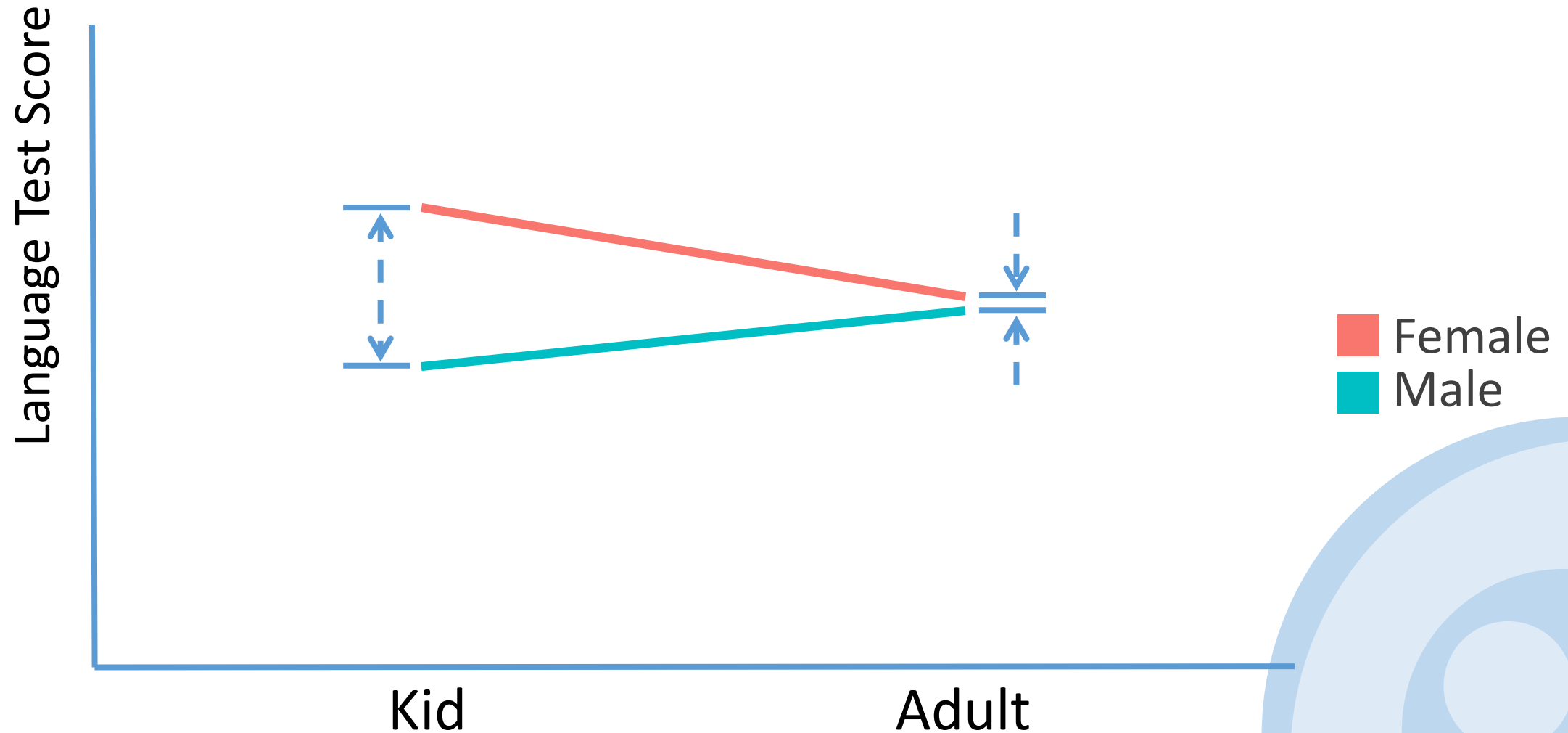
Main Effect / Interaction / Simple Effect



Main Effect / Interaction / Simple Effect



Main Effect / Interaction / Simple Effect



Summarizing the ANOVA test results

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
age	1	45	44.9	0.425	0.51528	
gender	1	904	904.1	8.552	0.00384	**
age:gender	1	748	747.7	7.074	0.00844	**
Residuals	206	21776	105.7			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

- **Main effect of age:** We _____ that there is a main effect of age, $F(1,206) = \underline{\hspace{1cm}}$, $p = \underline{\hspace{1cm}}$. We _____ that first graders ($M_{\text{first_grader}} = 68$, $SD_{\text{first_grader}} = 10.9$) are better language learners compared to adults (...), or vice versa.
- **Main effect of gender:** We _____ that there is a main effect of gender, $F(1,206) = \underline{\hspace{1cm}}$, $p = \underline{\hspace{1cm}}$. We _____ that female ($M_{\text{female}} = 70$, $SD_{\text{female}} = 10.3$) are better language learners compared to male (...)
- **Interaction:** We _____ that there _____ an interaction between age and gender, $F(1,206) = \underline{\hspace{1cm}}$, $p = \underline{\hspace{1cm}}$.
(Describe the interaction pattern, if any).

Effect Size (% Variance explained)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
age	1	45	44.9	0.425	0.51528	
gender	1	904	904.1	8.552	0.00384	**
age:gender	1	748	747.7	7.074	0.00844	**
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Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

$$\eta_{age}^2 = \frac{SS_{age}}{SS_{total}} = \frac{45 + 904 + 748 + 21776}{(45 + 904 + 748 + 21776)} = \text{---}\%$$

Power Analysis for two-way ANOVA

- Power analysis should be done *before* running the experiment
- Pick a factor / interaction of interest, estimate the % variance explained

```
# import the pwr library  
library("pwr")
```

```
# follow the syntax  
pwr.anova.test(f = NA, k = NA, n = NULL, power = NULL)
```

- With an estimated effect size of 0.3, to achieve a power of 80%, what is the sample size needed?

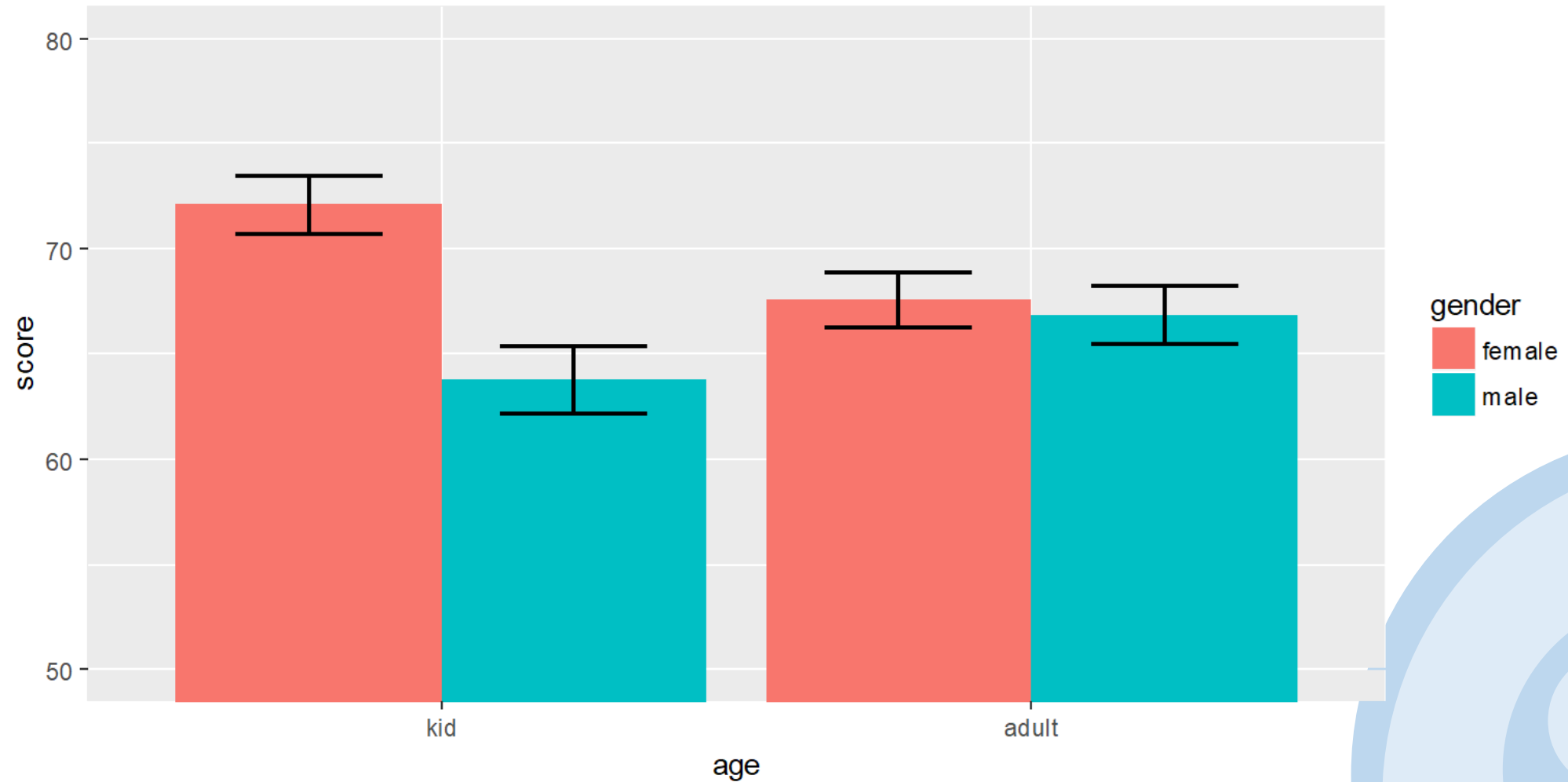
```
# effect size = 0.3, power = 0.8  
pwr.anova.test(f = __ , k = __ , n = __ , power = __ )
```

For practical use: Simple Effect

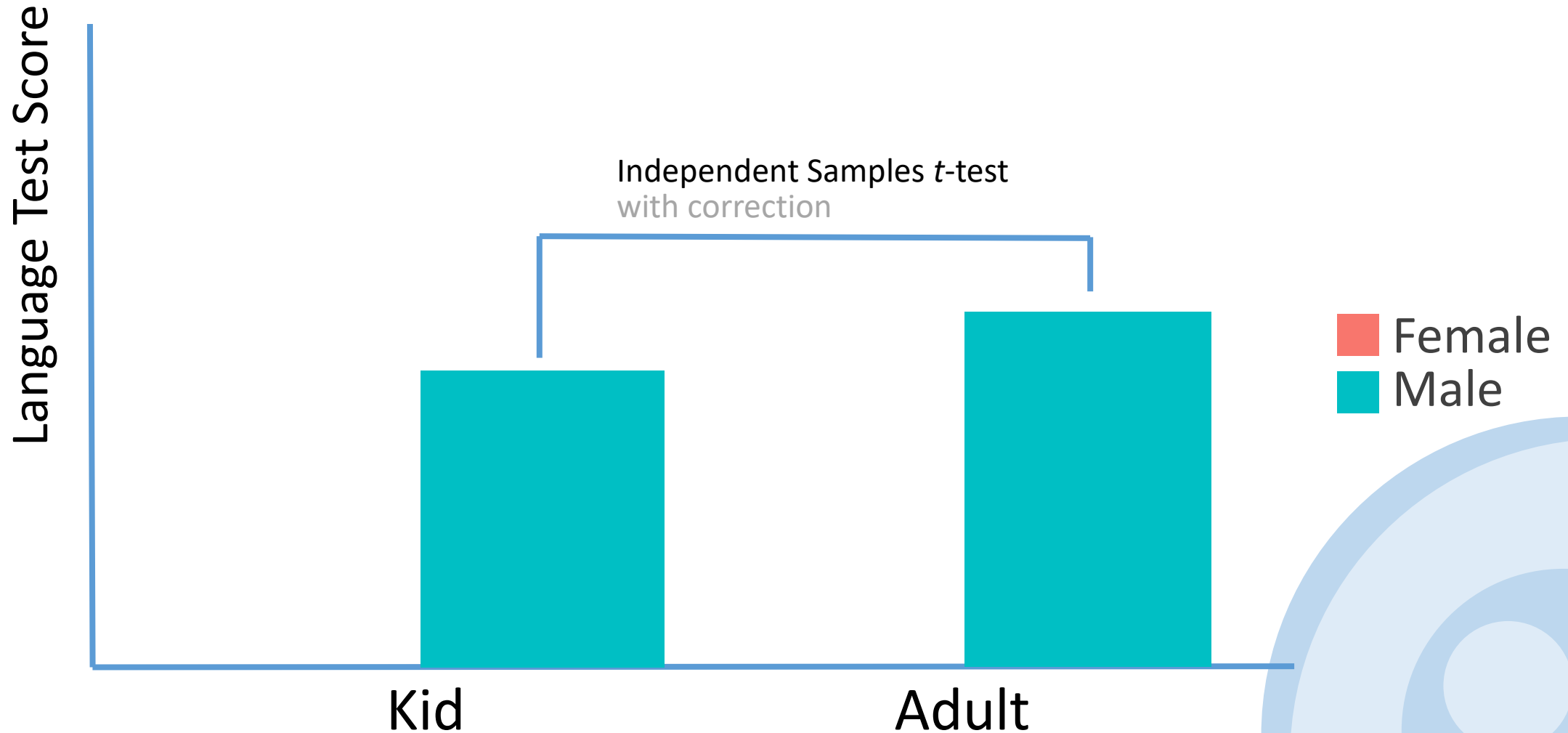
- If you have a baby boy, should you put him in Chinese school to learn Cantonese in first grade, or wait until he is an adult?
 - Main effect is not answering the question
It tells you whether female are better than male in learning a second language, or whether kids are better than adults in learning a second language
 - Interaction maybe helpful, but knowing how well female do is not helpful
- What we want to know is:
As male grow up, does the language learning skill get *worse*?



Main Effect / Interaction / Simple Effect



Main Effect / Interaction / Simple Effect



Simple Effect for the two male groups

```
t.test(score ~ age, data = language[language$ ____ == "____",],  
       var.equal = TRUE)
```



Simple Effect for the two male groups

- To account for the multiple simple effects performed:
p-value should be multiplied by number of simple effects performed

```
t.test(score ~ age, data = language[language$gender == "male",],  
       var.equal = TRUE)
```

Two Sample t-test

data: score by age
t = -1.4633, df = 98, p-value = 0.1466
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-7.232766 1.093372
sample estimates:
mean in group kid mean in group adult
63.76667 66.83636

$$df_{\text{total}} = df_1 + df_2 - 2$$

Bonferroni correction: p-value = 0.5864

×4

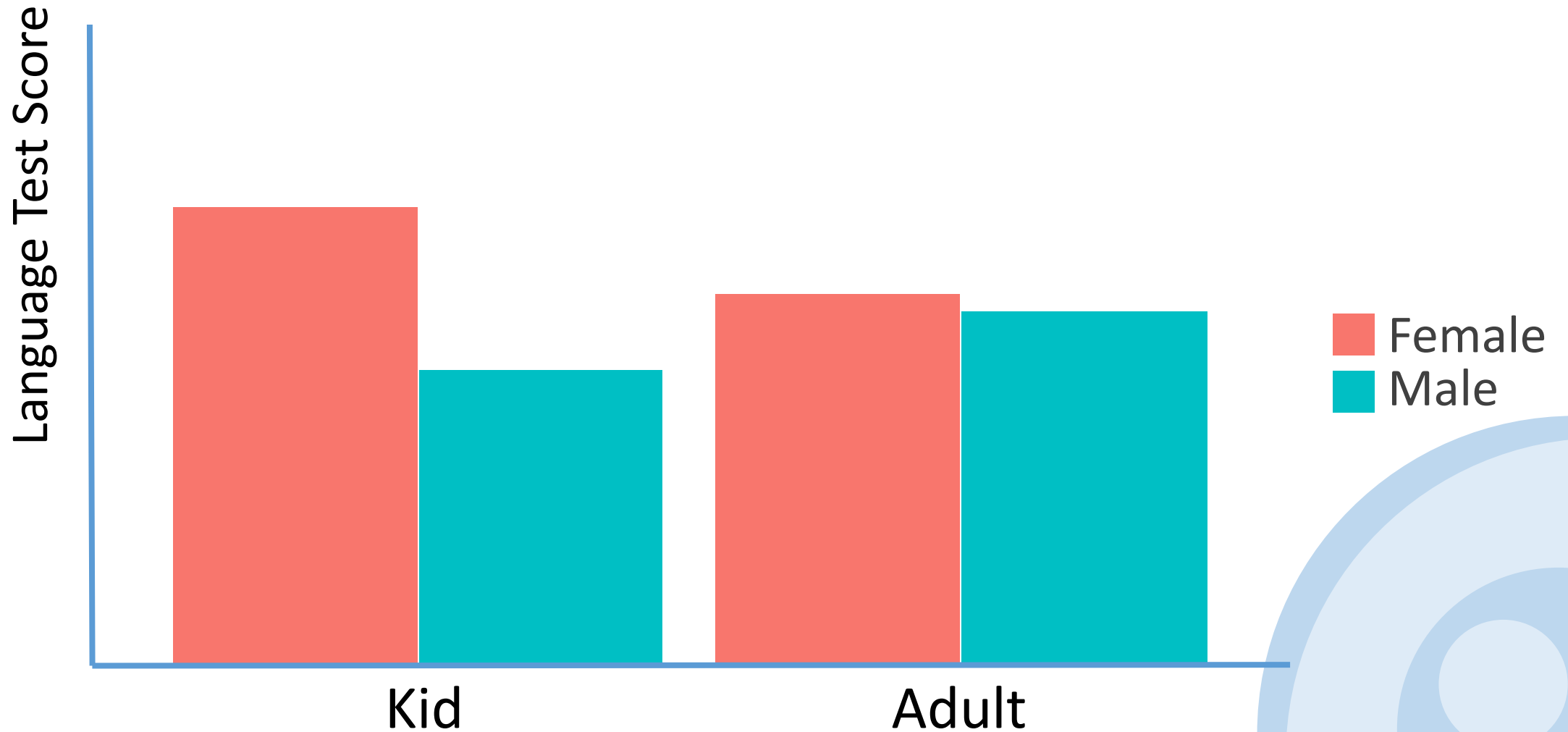


Post-hoc test

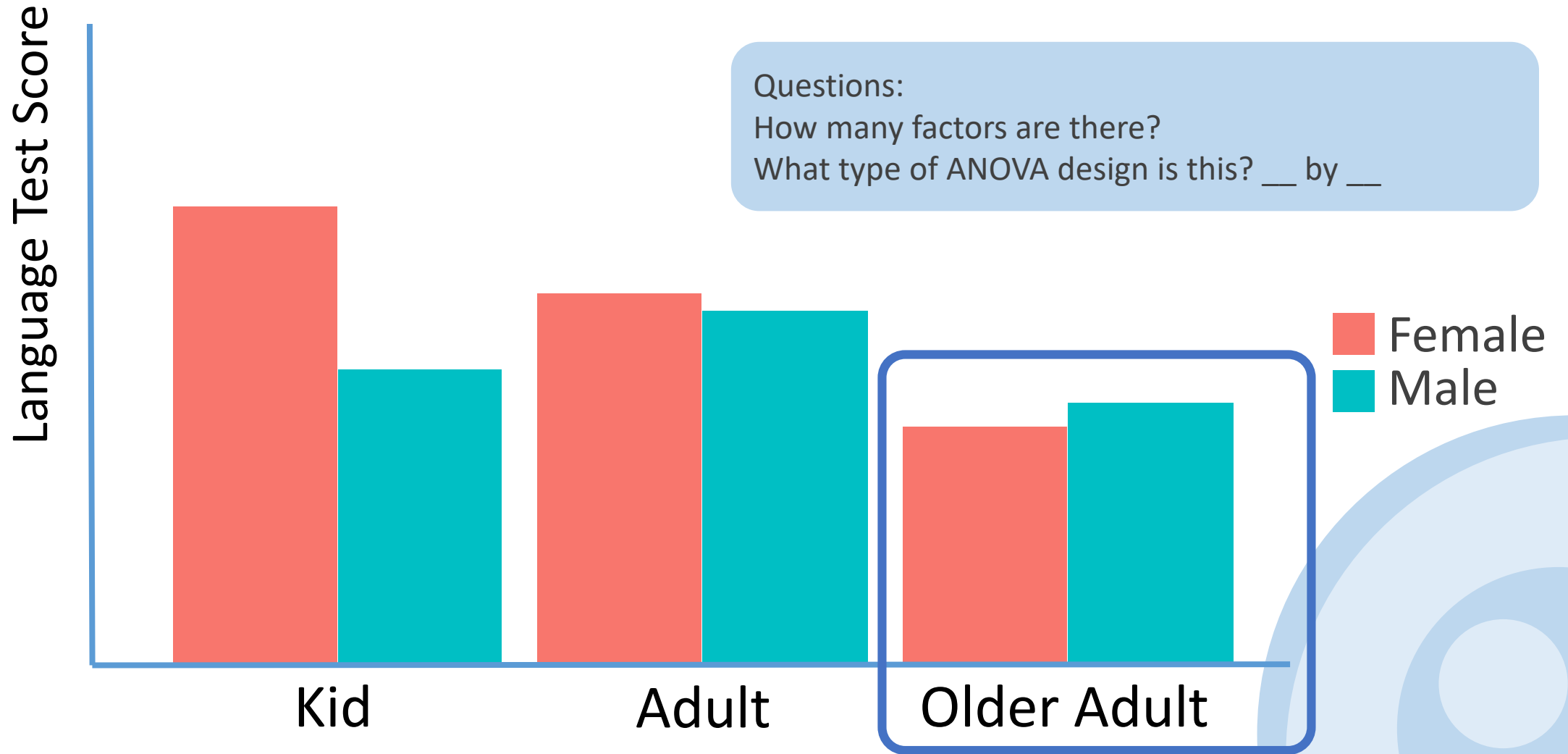
- If you have:
 - a significant result in one of the factors
 - And three or more conditions within a factor, you will need a post hoc test



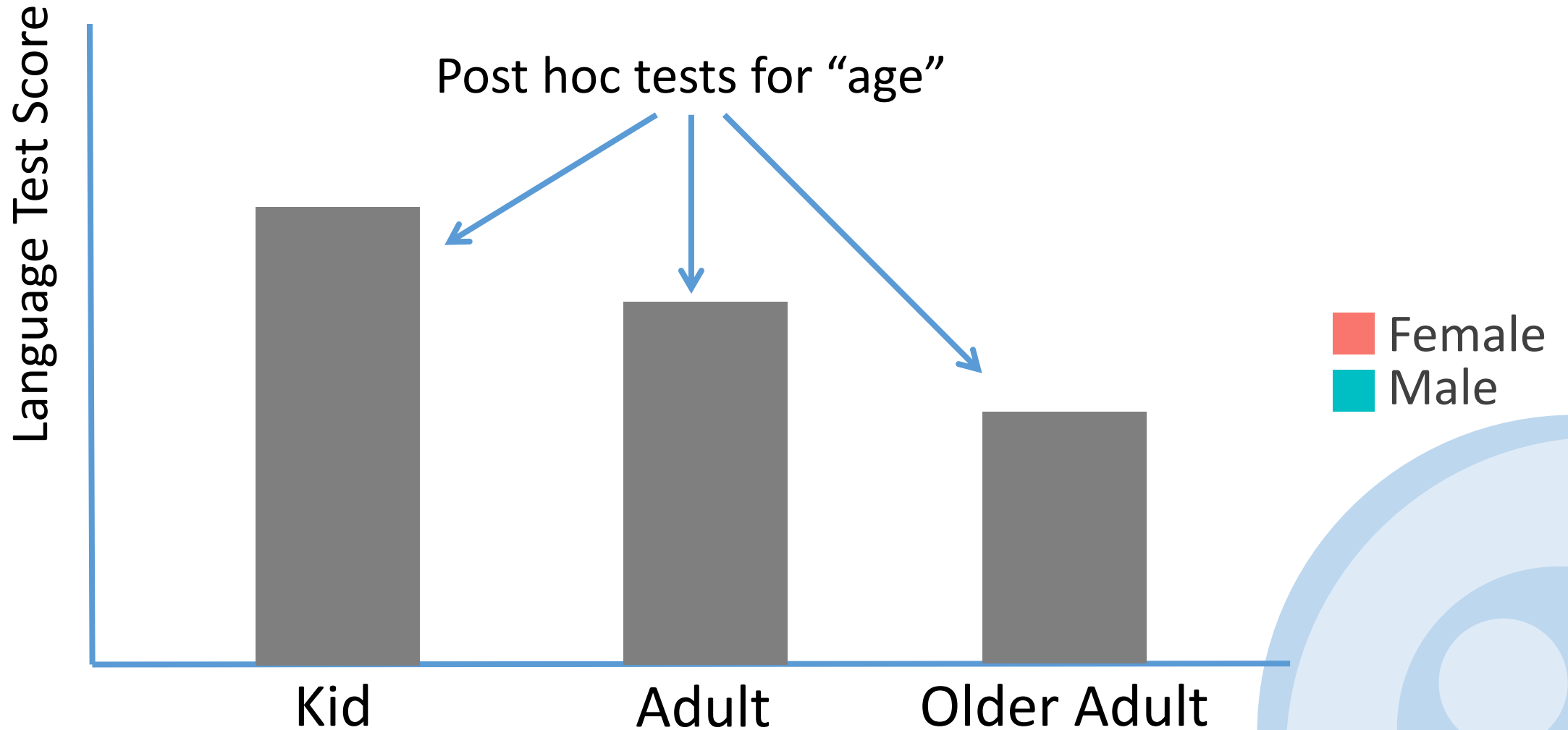
Original Design



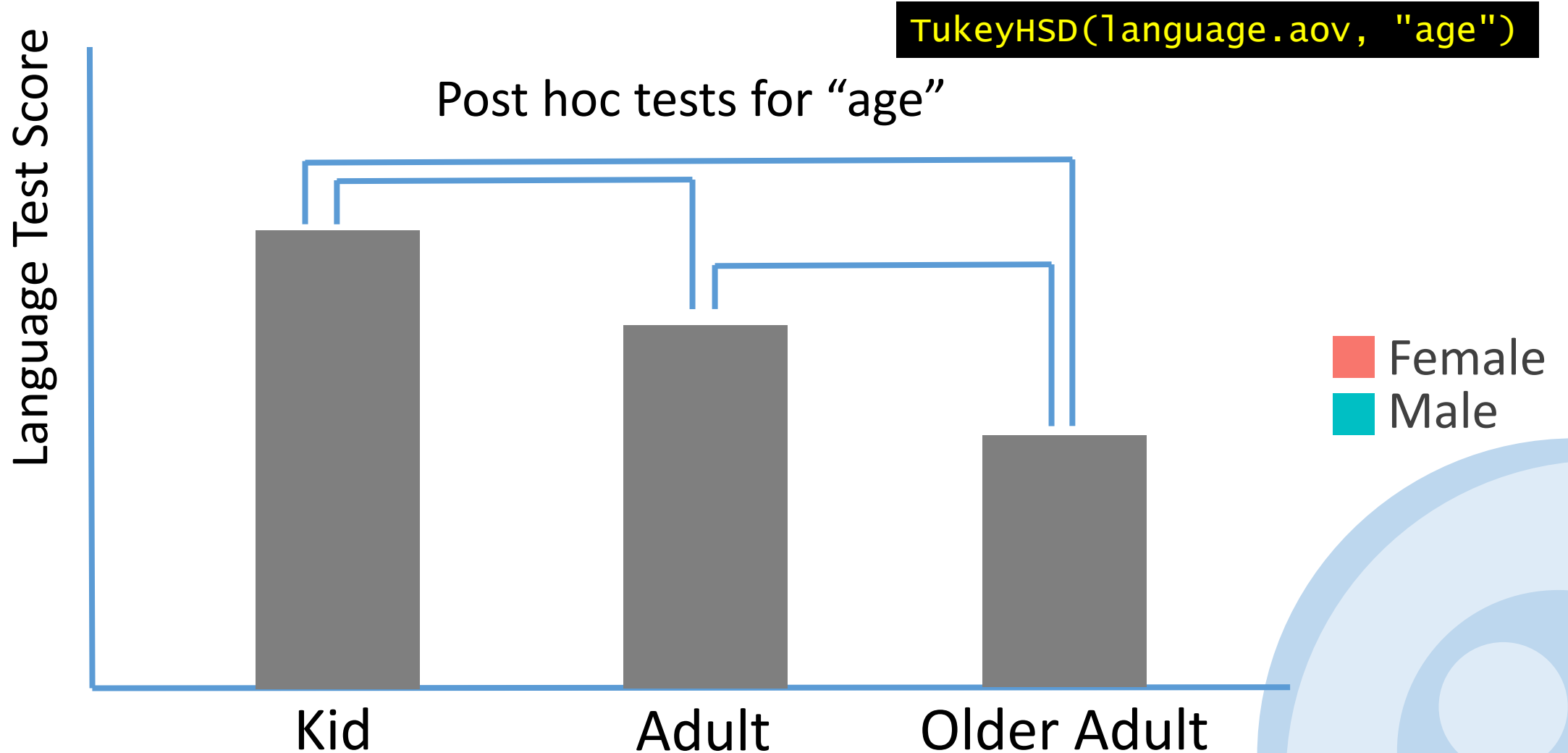
A new “Older Adult” Group



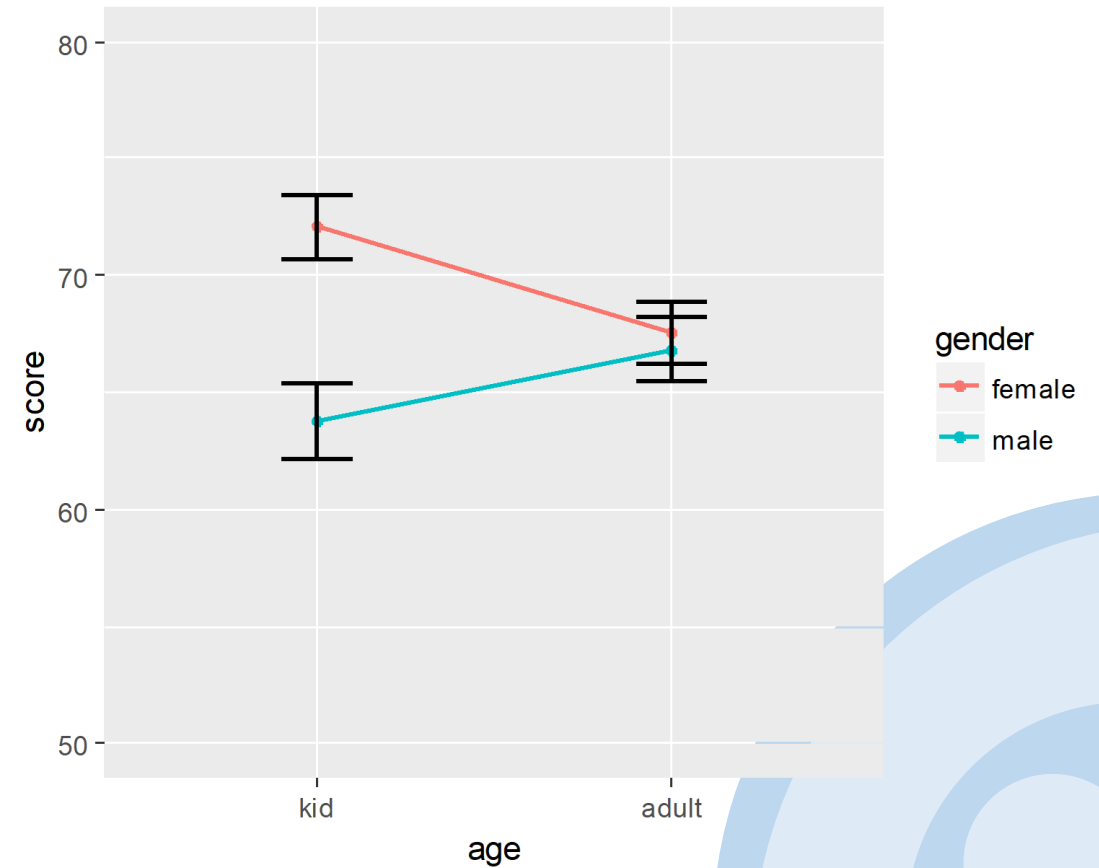
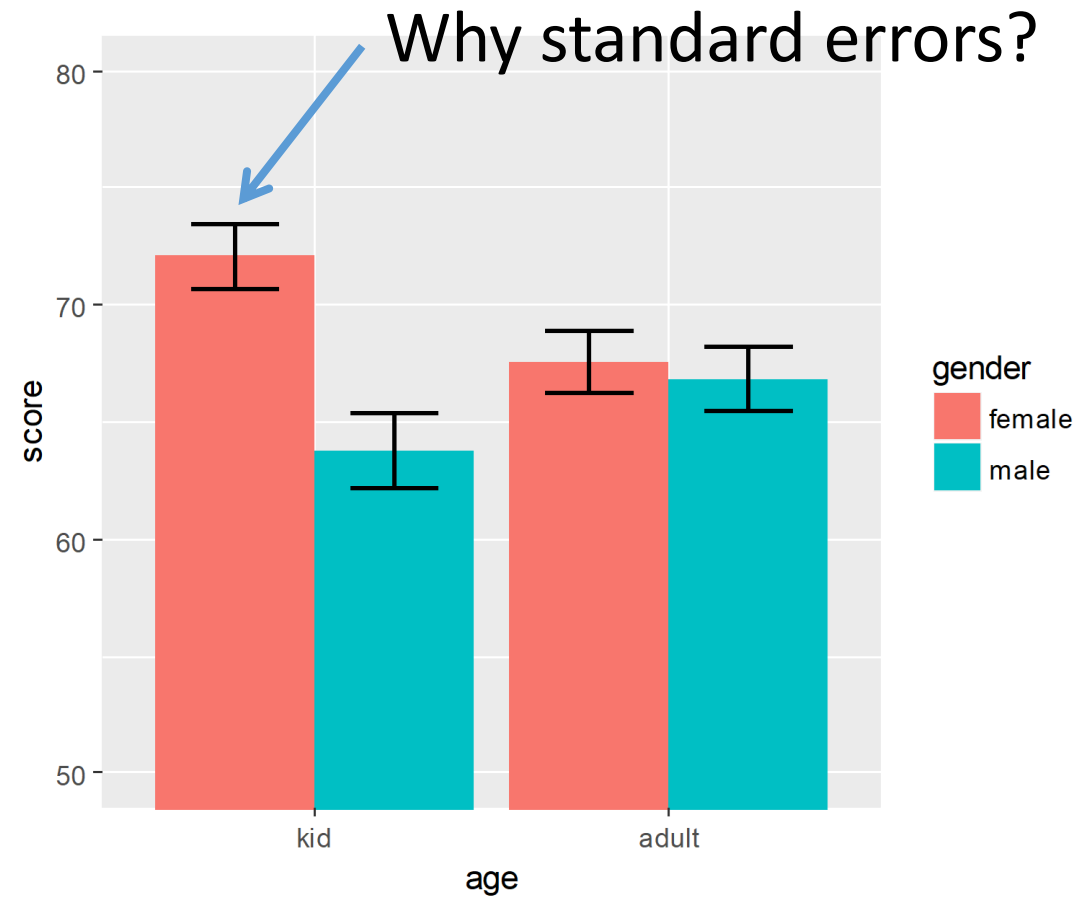
A new “Older Adult” Group



Tukey's Honestly Significance Difference Test



Choice for Visualization



Error bars denote standard errors of the means

Choice for Visualization

Bar chart

- Discrete Factors (?)
- Main Effects (?)

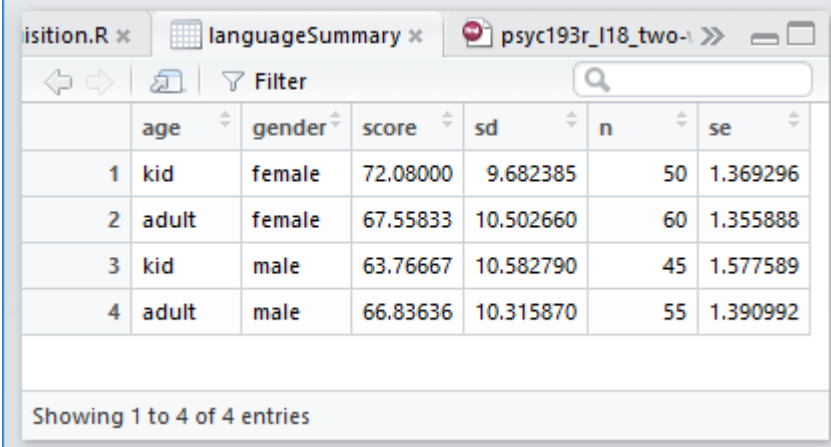
Line chart

- Continuous Factors (?)
 - Seeing trends
- Interaction (?)
- Comparing group differences



Summary Data Frame

- Create a new data frame called languageSummary
- Aggregate scores by the two factors
 - `aggregate()`
- Also find:
 - Standard deviation of each group
 - Number of participants
 - Standard error of each group (from *sd* and *n*)
- Merge all information into a single data frame
 - `cbind()`



The screenshot shows an RStudio window with a data frame named 'languageSummary'. The data is summarized by age and gender groups. The table displays the following information:

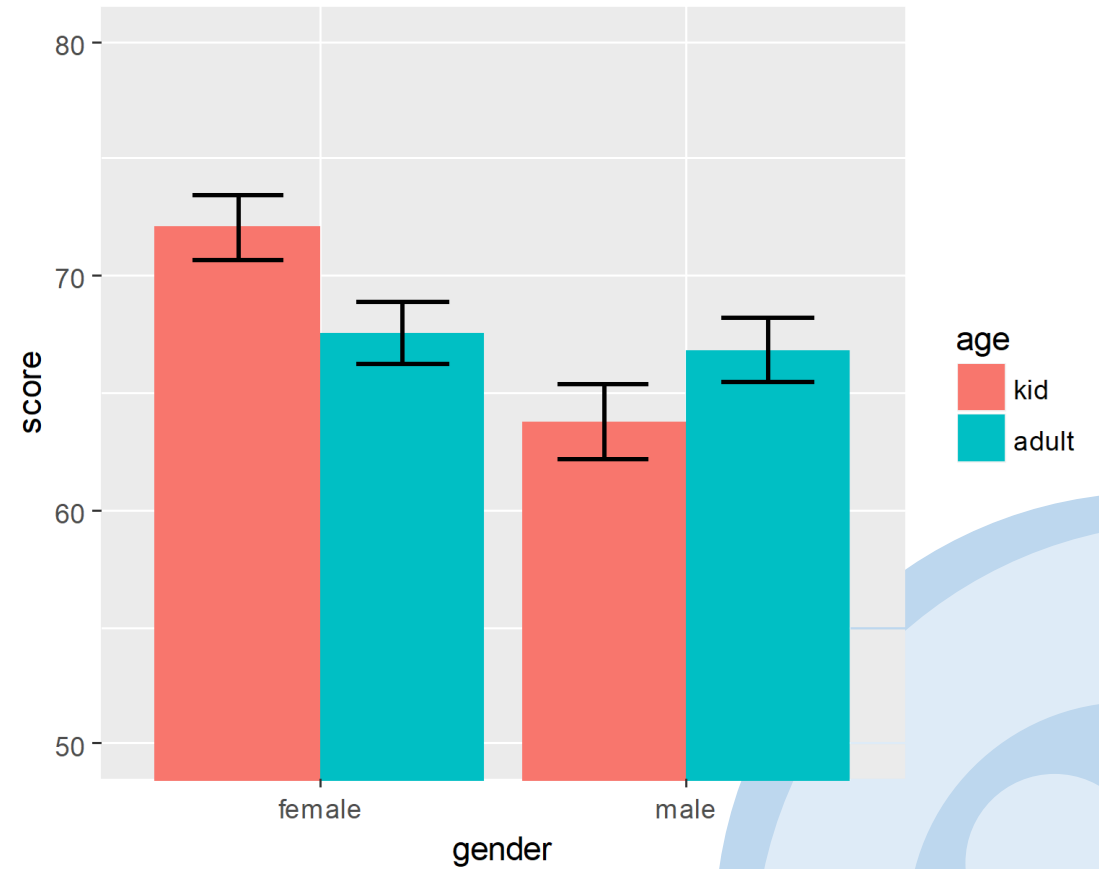
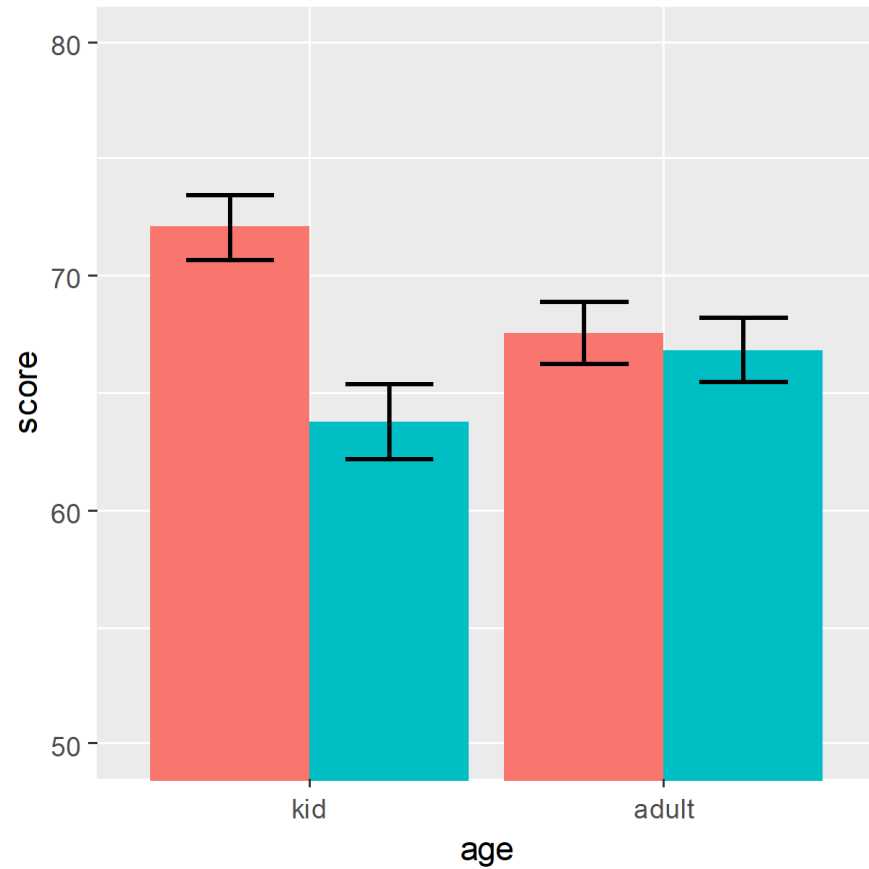
	age	gender	score	sd	n	se
1	kid	female	72.08000	9.682385	50	1.369296
2	adult	female	67.55833	10.502660	60	1.355888
3	kid	male	63.76667	10.582790	45	1.577589
4	adult	male	66.83636	10.315870	55	1.390992

Showing 1 to 4 of 4 entries

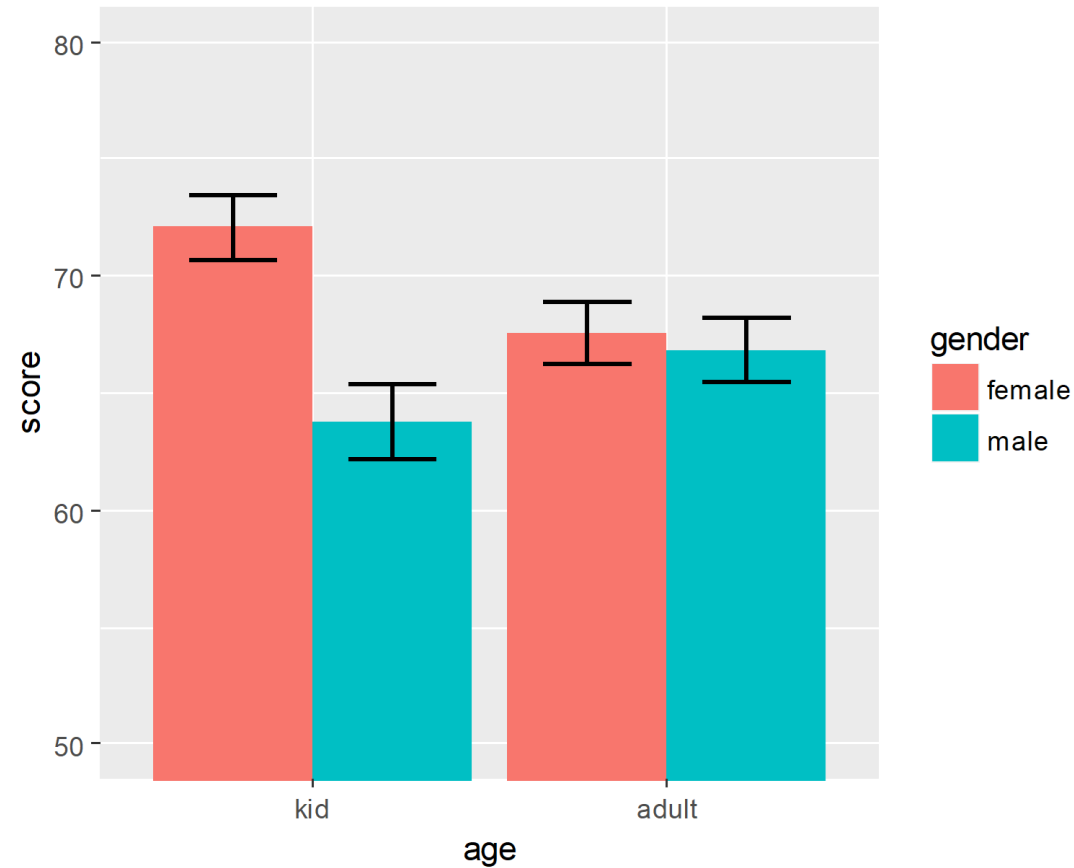
```
# find the group means
languageSummary = aggregate(score ~ ____ * _____ ,
  data = language, FUN = ____ )
# find the group standard deviations
languageSummary.sd = aggregate(score ~ ____ * _____ ,
  data = language, FUN = ____ )
# rename the column
names(languageSummary.sd )[ _ ] = "sd"
# find number of participants in each group
languageSummary.n = aggregate(score ~ ____ * _____ ,
  data = language, FUN = _____ )
# rename the column
names( languageSummary.n )[ _ ] = "n"
```

```
# merge all the statistics above into "languageSummary"
languageSummary = cbind( ____ , ____ , ____ )
names(languageSummary)[4] = "sd" # rename the column
names(languageSummary)[5] = "n" # rename the column
# find standard errors
languageSummary$se = ____ / ____
```

Basic Bar Chart (age or gender in x-axis?)

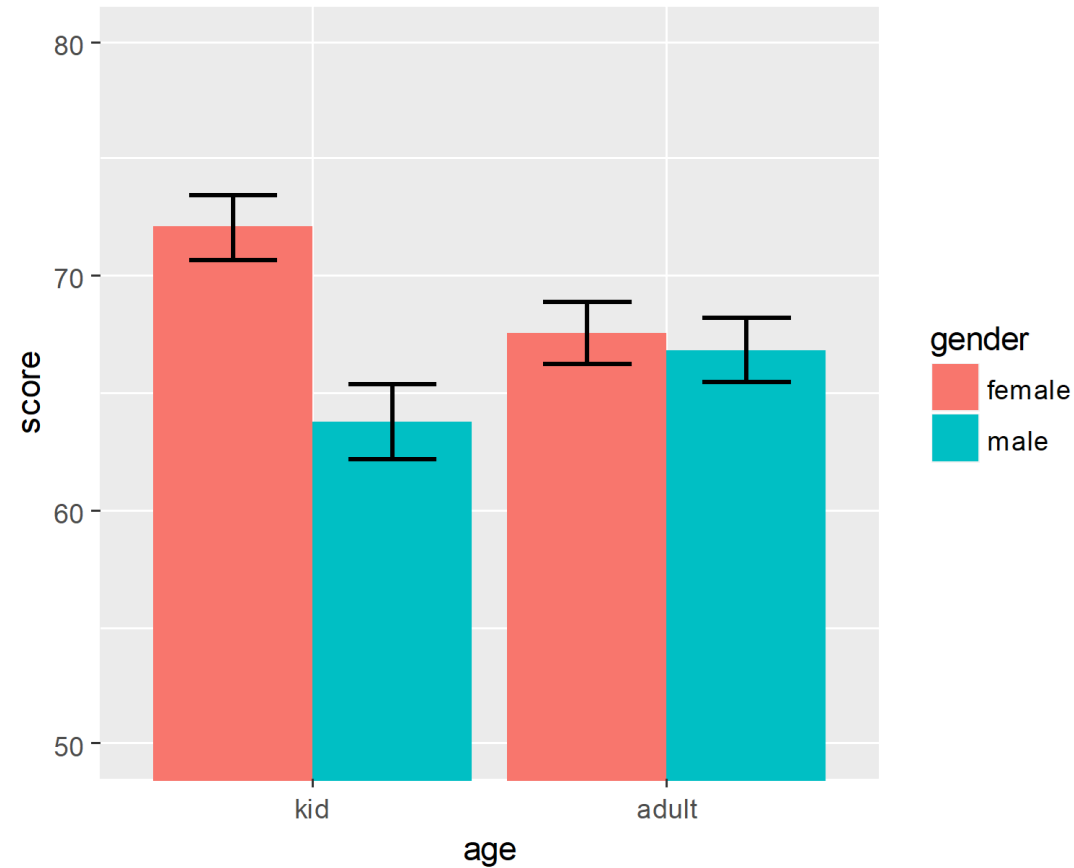


Basic Bar Chart



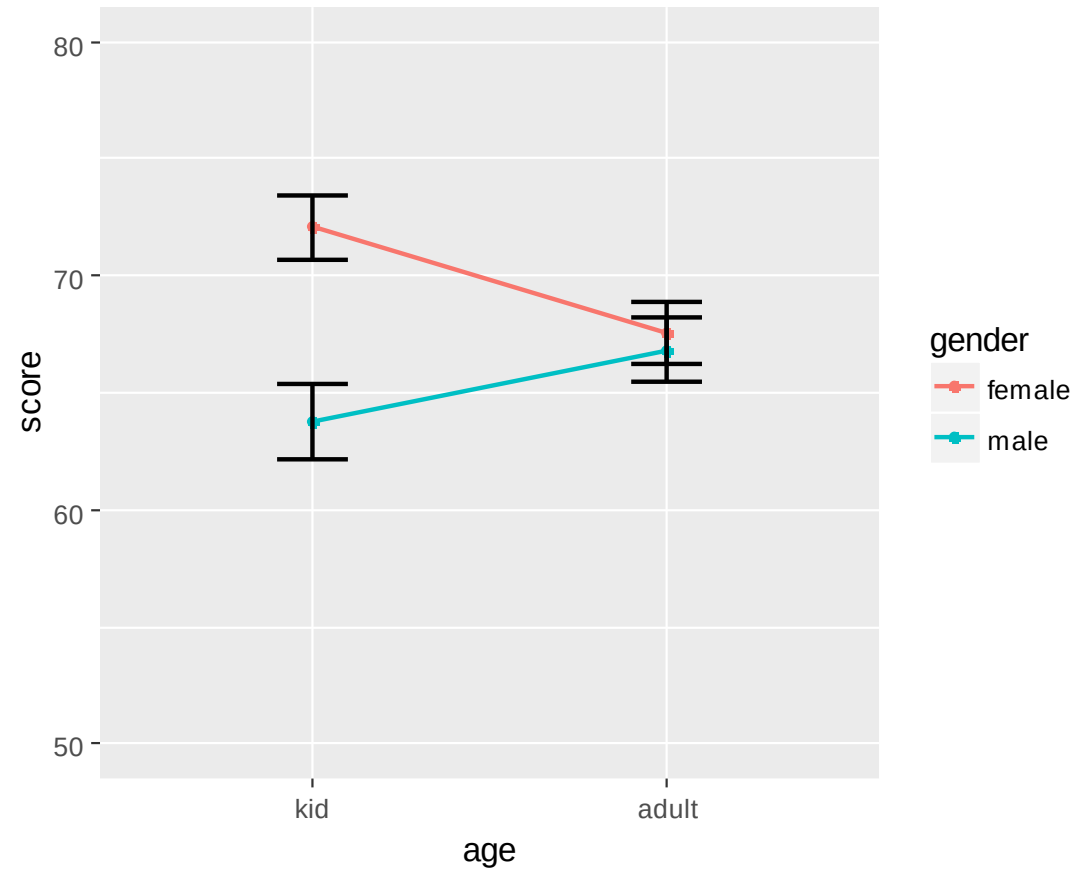
```
ggplot(data = __ ,  
  aes(x = __ , y = __ ,  
    fill = __ )) +  
  geom_bar(position=position_dodge(),  
    stat="identity") +  
  geom_errorbar(  
    aes(ymax = score + se,  
      ymin = score - se),  
    position=position_dodge(.9))
```

Basic Bar Chart



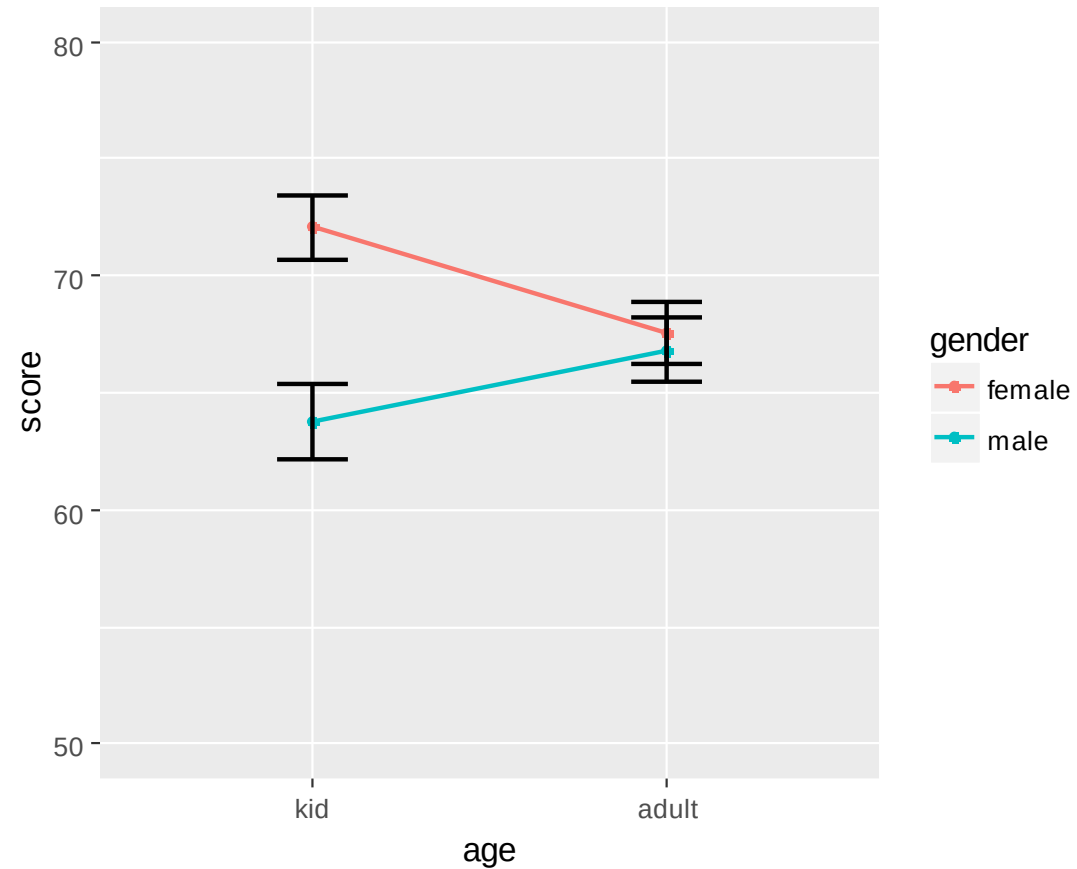
```
ggplot(data = ___,  
  aes(x = data / data structure_,  
    fill = _____)) +  
  geom_bar(position=position_dodge(),  
    stat="identity") +  
  geom_errorbar(  
    aes(ymax = score + se,  
      ymin = score - se,  
      position=position_dodge(.9)))
```

Basic Line Graph



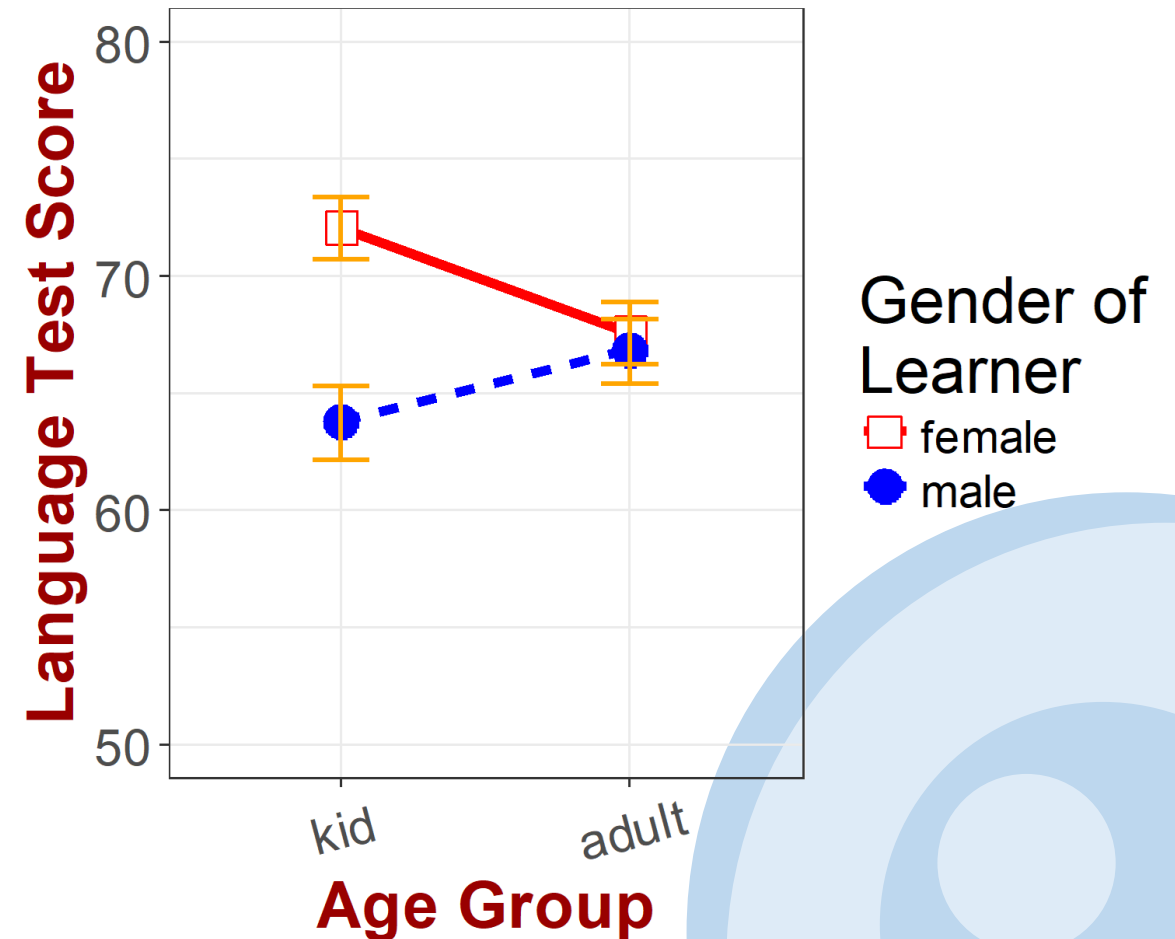
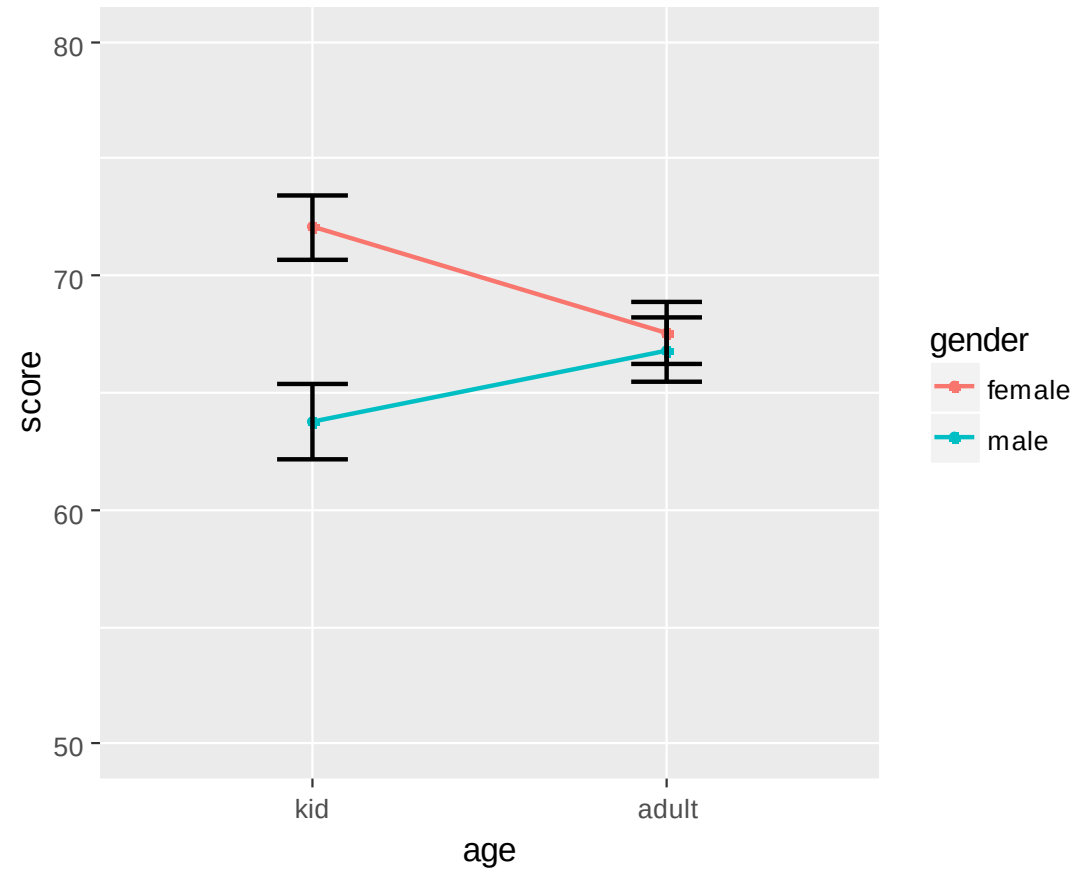
```
ggplot(data= _____ ,  
  aes(x= _____ , y= _____ , group= _____ ,  
    color= _____ )) +  
  geom_line() +  
  geom_point() +  
  geom_errorbar(  
    aes(ymax = score + se,  
      ymin = score - se))
```

Basic Line Graph



```
ggplot(data= _____ ,
  aes(x= _____ data / data structureoup= _____ ,
    color= _____ )) +
  geom_line() type of
  geom_point() graph
  geom_errorbar(
    aes(ymax=score + se,
      ymin = score - se))
```

Most of the features can be changed



Wrap up Two-way ANOVA

- **2 Factors / IVs:**
both nominal or ordinal
Depending on the *levels*
each factor has:
__ by __ design
- **DV:** interval or ratio
- **Main Effect:**
Consider only one factor at a time, look for difference in means
- **Interaction** (magnitude and polarity):
Differences between group differences (e.g., gender differences in two age groups)
- **Simple Effect:**
Difference between levels of a factor (e.g., among male participants, the change when they grow up)
- **Post-hoc Test:**
When a factor has multiple levels

ANOVA vs Linear model (Not in the exam)

```
language.aov = aov(score ~ age * gender, data = language)
library(car)
Anova(language.aov, type="III")
```

	Sum Sq	Df	F value	Pr(>F)
(Intercept)	259776	1	2457.4665	< 2.2e-16 ***
age	558	1	5.2749	0.0226404 *
gender	1637	1	15.4845	0.0001137 ***
age:gender	748	1	7.0736	0.0084383 **
Residuals	21776	206		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```
language.lm = lm(score ~ age * gender, data = language)
summary(language.lm)
```

```
lm(formula = score ~ age * gender, data = language)
```

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	72.080	1.454	49.573	< 2e-16 ***
ageadult	-4.522	1.969	-2.297	0.022640 *
gendermale	-8.313	2.113	-3.935	0.000114 ***
ageadult:gendermale	7.591	2.854	2.660	0.008438 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Limitations

- For one-way and two-way ANOVA, we only covered between-subjects design
- Within-subjects ANOVA can be helpful sometimes:
 - Google is your friend: "two-way repeated measures anova R"
 - The interpretation is pretty similar to between-subjects designs

