EDF 5401 Practice Final

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Physics Playground Background

The Game

Physics Playground is a game for teaching physics. One part of the program is learning supports. There were two kinds of learning supports:

- *Cogntive Supports*: Short videos explaining the physics.
- *Affective Supports*: Motivational messages and diversions designed to help alleviate frustration.

There are matched pretests and posttests which are divided into four parts:

- `NearECT` — Energy can transfer (ECT), near transfer (similar to the game) items
- `FarECT` — Energy can transfer (ECT), far transfer (not similar to the game) items
- `NearPOT` — Properties of torque (POT), near transfer
- `FarPOT` — Properties of torque (POT), far transfer

More information about the game and the experiment can be found at https://pluto.coe.fsu.edu/PhysicsDataPlayground/.

The support efficacy experiment and key variables

The experiment is a bit complex, with half of the student getting the ECT game levels and posttest in the first half of the experiment and the others in the second half.
For simplicity we will work with just the ECT-first: `Topic1=="ECT"`.

For these students, there are three condition groups (`Condition`):

- `A` – Cognitive Supports Only
- `C` – Cognitive and Affective Support

- `F` – No supports (control)

The variables, `CognitiveSupports` and `AffectiveECT` are logical variables describing whether or not the cognitive supports and the affective supports were present (during the first half of the study).

The pretest score is labeled `ECT` and the posttest score is labeled `ECTpost`.
There is also a `NearECT` and `NearECTpost` (just the near transfer items) and a `FarECT` and `FarECTpost` (far transfer items).

Additional covariates

`Age` Self-reported age in years.
`Sex, Gender` Self-reported gender
`White` Whether or not the subject identified as White.
`Gaming` "How often do you play video games?" Ordinal, possible values:
`Never`, `Once a month or less`, `Once a week`, `3-4 times a week`, `Every day`
`Physics` "Have you studied Physics?" Possible answers `Yes`, `No`.
`POT` Score on the properties of torque physics pretest.
`PhysicsScore` `POT + ECT`
`IMI_Enj` Enjoyment subscale of the intrinsic motivation inventory (IMI)
`IMI_Eng` Engagement subscale of the IMI
`IMI_PC` Player confidence subscale of the IMI
`IMI_Effort` Effort subscale of the IMI
`IMI_Frust` Frustration subscale of the IMI
`IMI_Value` Value of experience subscale IMI
`gold, silver, quit` The number of game levels in which the player received a gold trophy (solved the level with an efficient solution), silver trophy (solved the level, but did not meet the qualifications for efficiency), or abandoned the level without solving it.

Data Loading and cleaning

```
library(tidyverse)
library(DescTools)
library(rgl)
library(GGally)
```

Load the data (from the internet)

```
source("https://pluto.coe.fsu.edu/PhysicsDataPlayground/Data/AllMetadata.R")
PPIESFall2022 <-
  read_csv("https://pluto.coe.fsu.edu/PhysicsDataPlayground/Data/PPIESFall2022Full.csv",
           col_types=colAll)
```

Extract a subset of the data with just the cases/variables we are working with.

```
PPIESExtract <- PPIESFall2022 |>
  filter(Topic1=="ECT") |>
  select(all_of(c("StudyID", "Condition", "CognitiveSupports", "AffectiveECT",
                  "Age", "Sex", "White", "Gaming", "Physics",
                  "NearECT", "FarECT", "ECT",  "NearECTpost", "FarECTpost",
                  "ECTpost", "POT", "PhysicsScore",
                  "IMI_Enj", "IMI_Eng", "IMI_PC", "IMI_Effort", "IMI_Frust",
                  "IMI_Value",
                  "gold", "silver", "quit"))) |>
  na.omit()
summary(PPIESExtract)
```

```
  StudyID          Condition CognitiveSupports AffectiveECT         Age
Length:119         A:43      Mode :logical     Mode :logical   Min.   :12.00
Class :character   B: 0      FALSE:35          FALSE:78        1st Qu.:12.00
Mode  :character   C:41      TRUE :84          TRUE :41        Median :13.00
                   D: 0                                       Mean   :13.08
                   E: 0                                       3rd Qu.:14.00
                   F:35                                       Max.   :16.00
               Sex       White                          Gaming   Physics
Male             :62   Mode :logical   Never                :14   Yes:89
Female           :54   FALSE:29        Once a month or less:22   No :30
Other            : 0   TRUE :90        Once a week          :12
Prefer not to say: 0                   3-4 times a week     :44
Nonbinary        : 3                   Every day            :27

   NearECT          FarECT           ECT          NearECTpost
Min.   :0.000   Min.   :1.000   Min.   : 3.000   Min.   :0.000
1st Qu.:4.000   1st Qu.:4.000   1st Qu.: 7.000   1st Qu.:5.000
Median :5.000   Median :4.000   Median : 9.000   Median :6.000
Mean   :4.874   Mean   :4.412   Mean   : 9.286   Mean   :5.319
3rd Qu.:6.000   3rd Qu.:5.000   3rd Qu.:11.000   3rd Qu.:6.000
Max.   :8.000   Max.   :7.000   Max.   :14.000   Max.   :8.000
  FarECTpost       ECTpost           POT          PhysicsScore
```

```
Min.   :0.000   Min.   : 2.00   Min.   : 3.000   Min.   : 8.00
1st Qu.:4.000   1st Qu.: 9.00   1st Qu.: 6.000   1st Qu.:14.00
Median :5.000   Median :10.00   Median : 8.000   Median :17.00
Mean   :4.689   Mean   :10.01   Mean   : 7.504   Mean   :16.79
3rd Qu.:6.000   3rd Qu.:12.00   3rd Qu.: 9.000   3rd Qu.:20.00
Max.   :7.000   Max.   :15.00   Max.   :12.000   Max.   :24.00
   IMI_Enj         IMI_Eng          IMI_PC        IMI_Effort      IMI_Frust
Min.   : 1.0   Min.   : 3.00   Min.   : 6.00   Min.   : 7.00   Min.   : 3.0
1st Qu.: 8.5   1st Qu.:14.00   1st Qu.:14.00   1st Qu.:19.00   1st Qu.: 8.0
Median :10.0   Median :17.00   Median :17.00   Median :22.00   Median :11.0
Mean   :10.2   Mean   :16.18   Mean   :17.51   Mean   :22.01   Mean   :10.8
3rd Qu.:13.0   3rd Qu.:20.00   3rd Qu.:21.00   3rd Qu.:26.00   3rd Qu.:14.0
Max.   :14.0   Max.   :21.00   Max.   :28.00   Max.   :28.00   Max.   :21.0
  IMI_Value           gold            silver            quit
Min.   : 2.000   Min.   : 0.000   Min.   : 2.000   Min.   : 0.000
1st Qu.: 7.000   1st Qu.: 5.000   1st Qu.: 6.000   1st Qu.: 3.500
Median : 9.000   Median : 7.000   Median : 8.000   Median : 7.000
Mean   : 9.059   Mean   : 6.924   Mean   : 8.563   Mean   : 7.487
3rd Qu.:11.000   3rd Qu.: 9.000   3rd Qu.:10.000   3rd Qu.:11.000
Max.   :14.000   Max.   :16.000   Max.   :21.000   Max.   :25.000
```

Only three students who identify as nonbinary. Too small to analyze, so take them out.

Derieved variables

Gain Scores

```
PPIESExtract <- PPIESExtract |>
  mutate(ECTgain=ECTpost-ECT,
         NearECTgain=NearECTpost-NearECT,
         FarECTgain=FarECTpost-FarECT,
         LowECT= ECT<median(ECT))
```

The reason for LowECT will become apparent later.

```
PPIESExtract <- filter(PPIESExtract,Sex %in% c("Male","Female"))
```

Some changes for interpretability

Ages run from 12-16 (middle and high school students). Create an new variable `Age1` for subtracts 0, so it is essential years of schooling since elementary school.

Center physics variable to aid in interpretation.

```
PPIESExtract <- mutate(PPIESExtract,Age1=Age-12,
                       PhysicsCenter=PhysicsScore-mean(PhysicsScore))
```

It will be convenient (mainly for graphics) to have better labeled condition variable.

```
PPIESExtract$Supports <-
  factor(PPIESExtract$CognitiveSupports+PPIESExtract$AffectiveECT,
         levels=0:2,labels=c("None","COG only","COG+AFF"))
```

Enjoyment definition

For the logistic regression, we will define Enjoyed as `IMI_Enj >7` (This ranges from 2–14).

```
PPIESExtract <- mutate(PPIESExtract,Enjoyed=IMI_Enj>8)
```

Write this out in SPSS format so we can do a parallel analysis there.

```
haven::write_sav(PPIESExtract,"PPIESExtract.sav")
```

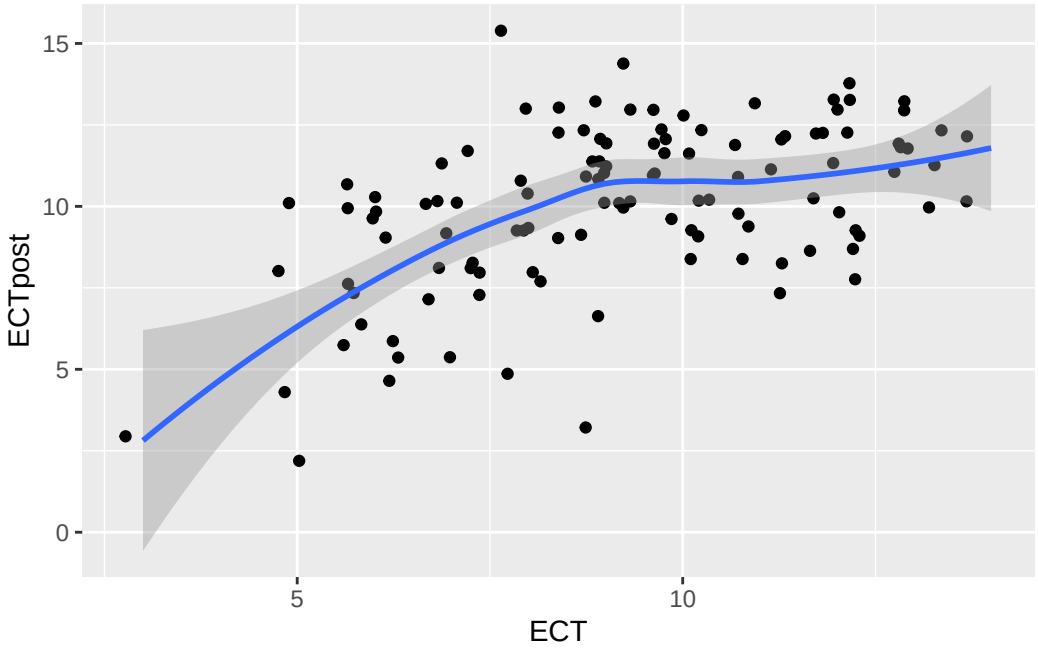
ANCOVA

The primary analysis will be an ANCOVA with `ECTpost` as the dependent variable, `ECT` as the covariate, and `CognitiveSupport` and `AffectiveECT` as the treatment variables. In addition we will explore other possible covariates.

Exploratory Analysis

```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost)) + geom_point(position="jitter") +
  geom_smooth()
```

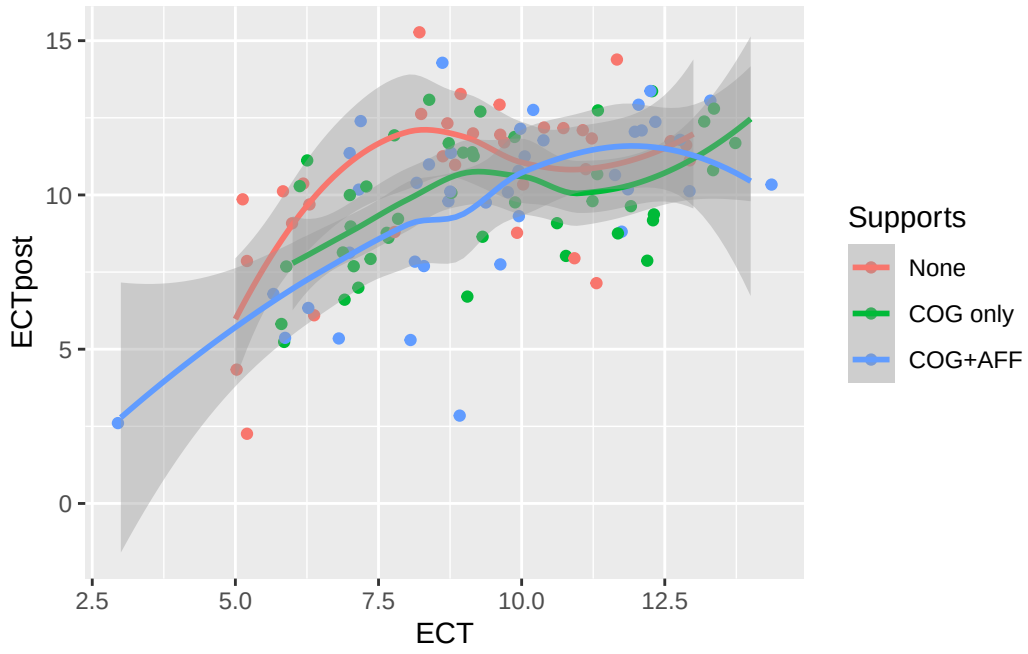
```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Treatment by condition breakdown

```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=Supports)) +
  geom_point(position="jitter") +
  geom_smooth()
```

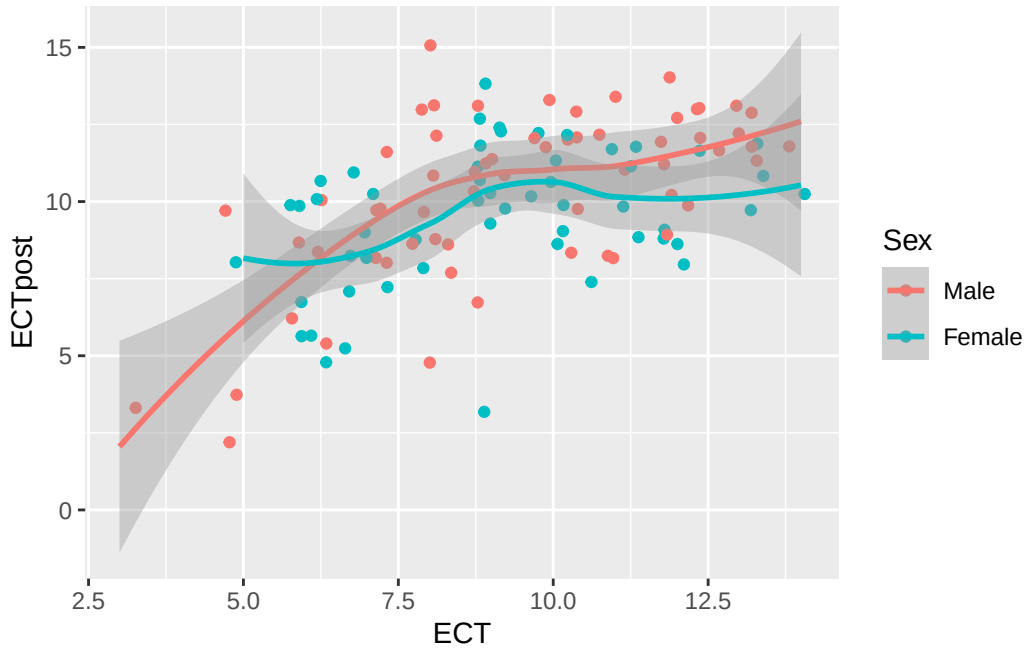
```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Demographic Breakdowns

```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=Sex)) +
  geom_point(position="jitter") +
  geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



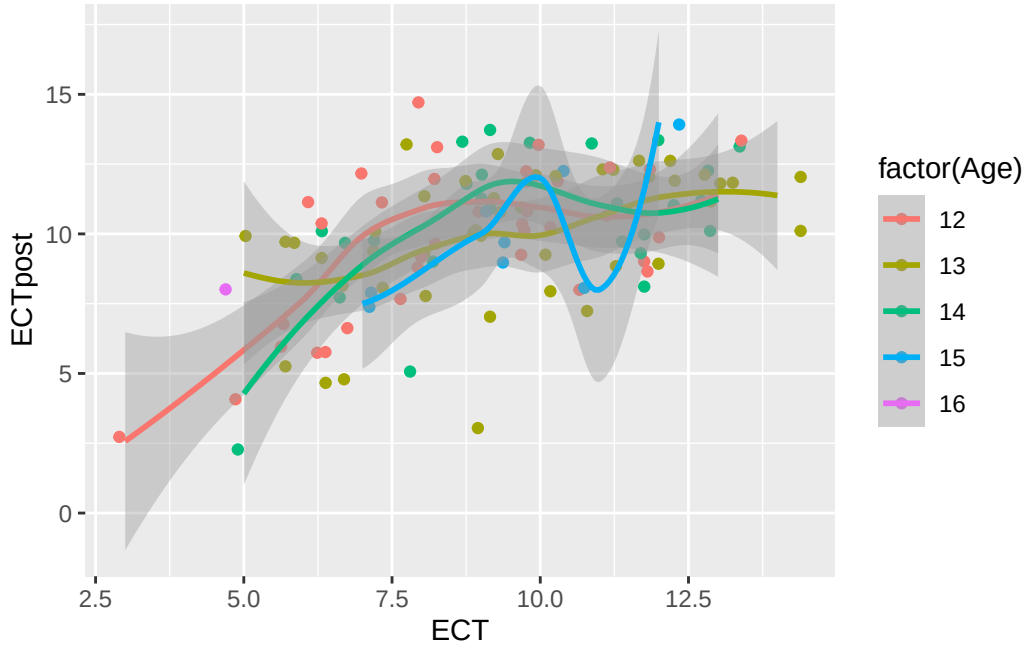

```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=factor(Age))) +
  geom_point(position="jitter") +
  geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: pseudoinverse used at 6.975

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: neighborhood radius 3.025

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: reciprocal condition number 4.961e-17

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: There are other near singularities as well. 4

Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : pseudoinverse used at
6.975
```

```
Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : neighborhood radius
3.025
```

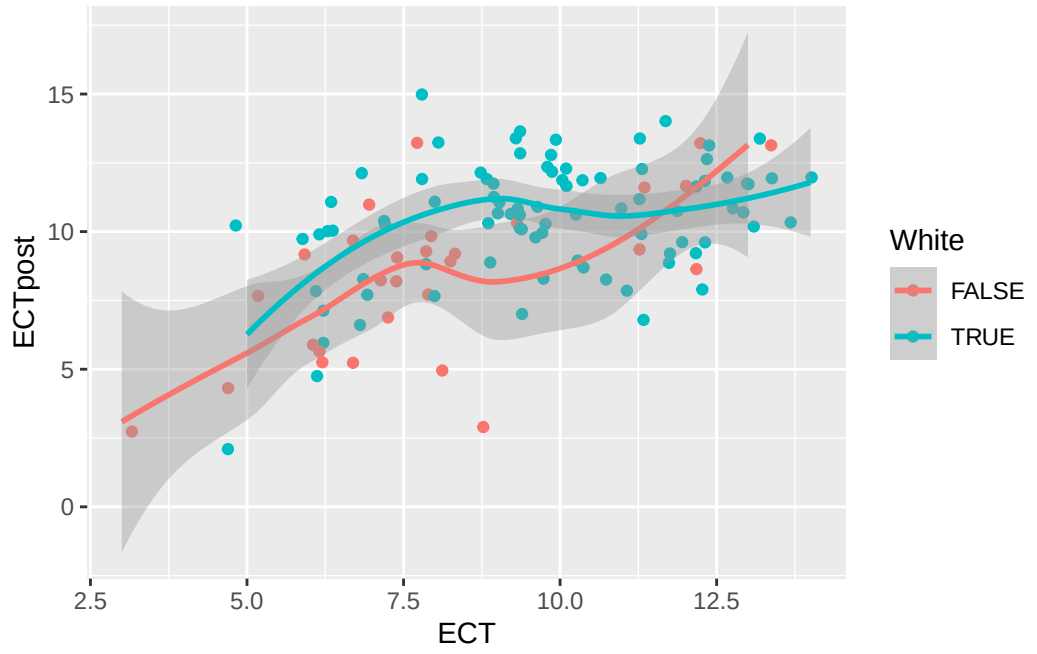
```
Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : reciprocal condition
number 4.961e-17
```

```
Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : There are other near
singularities as well. 4
```




```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=White)) +
  geom_point(position="jitter") +
  geom_smooth()
```

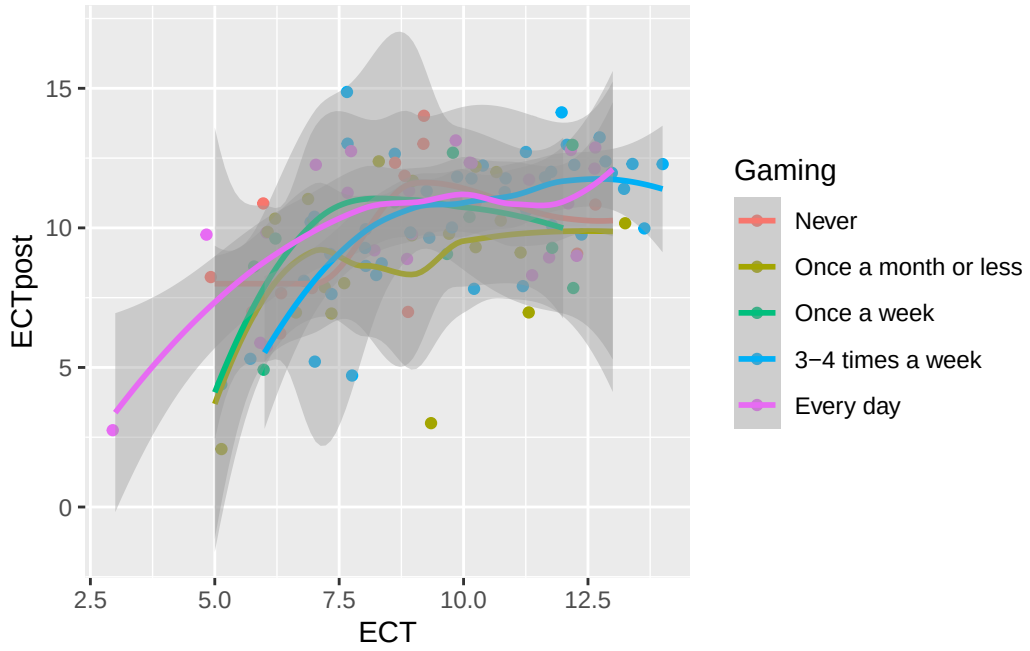
```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```




```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=Gaming)) +
  geom_point(position="jitter") +
  geom_smooth()
```

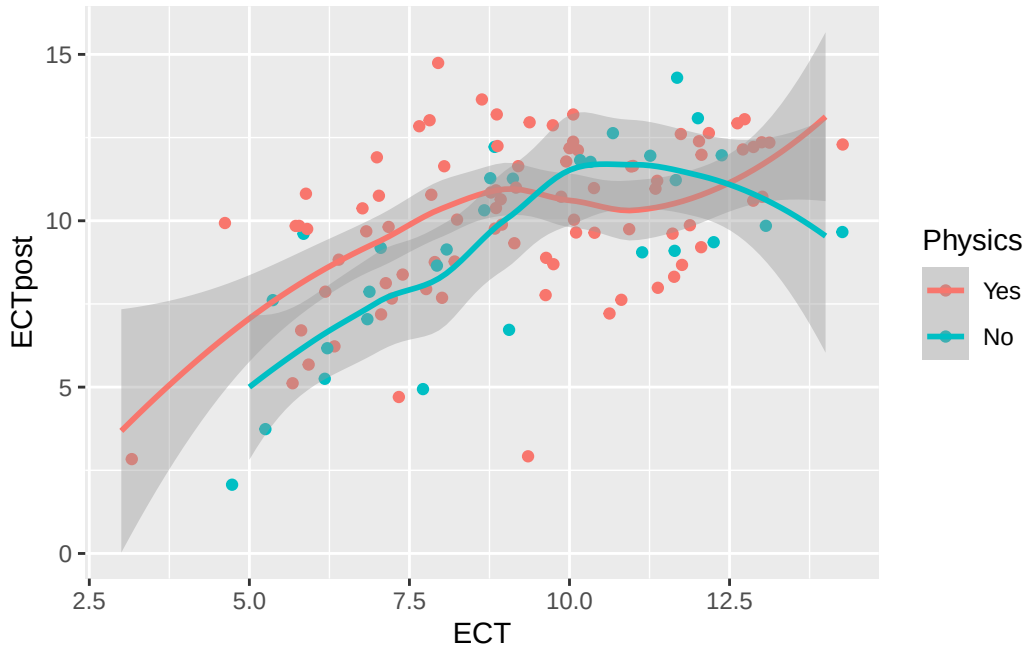
```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: pseudoinverse used at 7

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: neighborhood radius 2

Warning in simpleLoess(y, x, w, span, degree = degree, parametric = parametric,
: reciprocal condition number 4.0584e-17

Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : pseudoinverse used at 7

Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : neighborhood radius 2
```

```
Warning in predLoess(object$y, object$x, newx = if (is.null(newdata)) object$x
else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : reciprocal condition
number 4.0584e-17
```



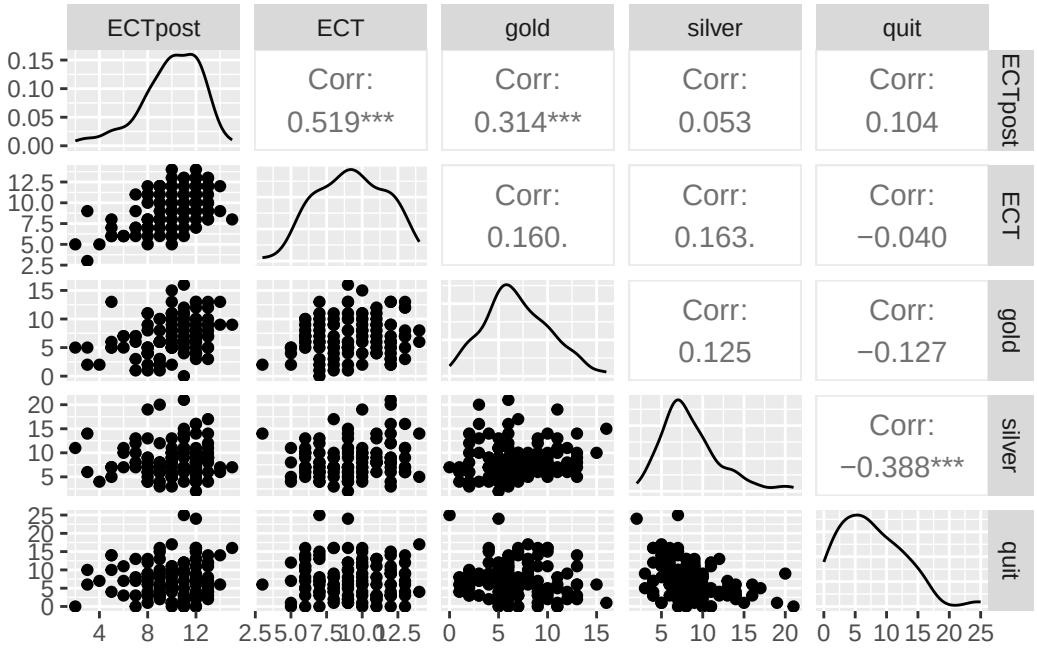

```
ggplot(PPIESExtract,aes(x=ECT,y=ECTpost,color=Physics)) +
  geom_point(position="jitter") +
  geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Look at the correlation between the trophy variables and ECT with a scatterplot matrix.

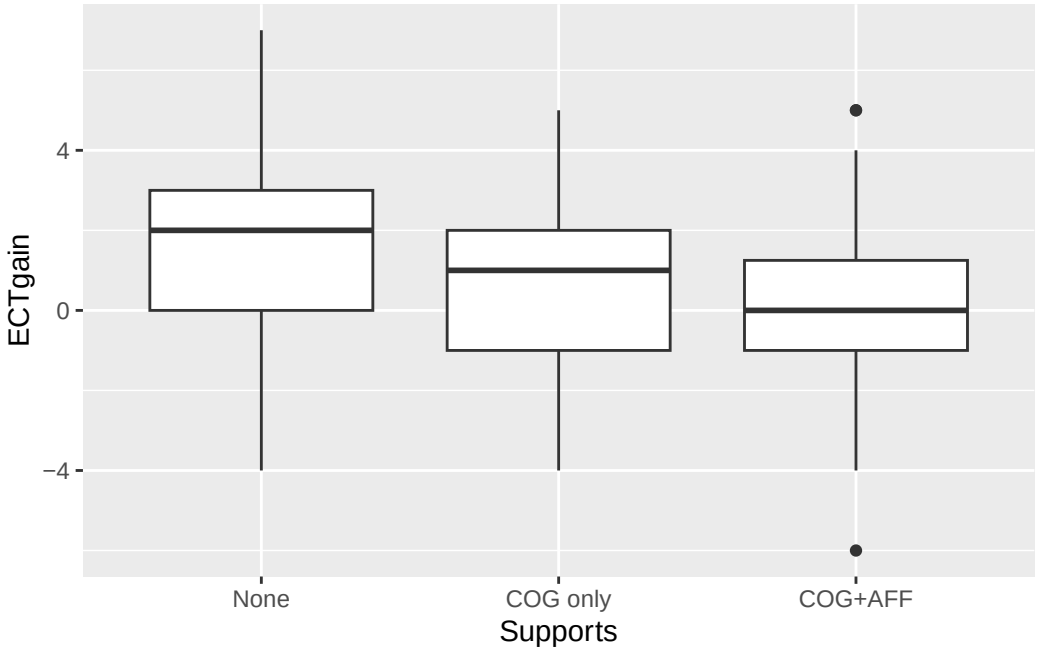
```
select(PPIESExtract,all_of(c("ECTpost","ECT","gold","silver","quit"))) |>
  ggpairs()
```



Treatment Effect

A = Cognitive Only C = Cogntivie + Affective F = Control (no supports)

```
ggplot(PPIESExtract,aes(x=Supports,y=ECTgain)) + geom_boxplot()
```



Baseline Model

```
ECTbase <- lm(ECTpost ~ ECT + Supports,data=PPIESExtract)
summary(ECTbase)
```

```
Call:
lm(formula = ECTpost ~ ECT + Supports, data = PPIESExtract)

Residuals:
   Min     1Q Median     3Q    Max
-6.487 -1.195  0.259  1.436  5.113

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

```
(Intercept)       5.45418    0.83271   6.550 1.81e-09 ***
ECT               0.55409    0.08309   6.668 1.02e-09 ***
SupportsCOG only -0.76882    0.49428  -1.555   0.1227
SupportsCOG+AFF  -0.95423    0.50343  -1.895   0.0606 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.133 on 112 degrees of freedom
Multiple R-squared:  0.2939,    Adjusted R-squared:  0.275
F-statistic: 15.54 on 3 and 112 DF,  p-value: 1.618e-08
```

ATI Model

```
ECTATI <- lm(ECTpost ~ ECT * Supports,data=PPIESExtract)
summary(ECTATI)
```

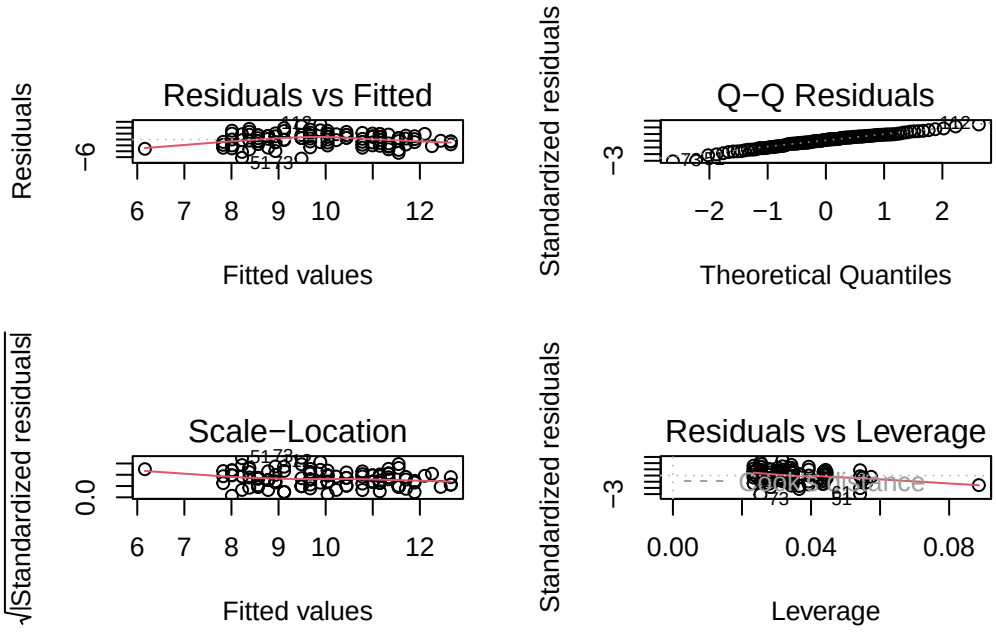
```
Call:
lm(formula = ECTpost ~ ECT * Supports, data = PPIESExtract)

Residuals:
    Min      1Q  Median      3Q     Max
-6.4208 -1.1708  0.3345  1.3457  5.1432

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)            5.1758     1.4036   3.687 0.000354 ***
ECT                    0.5851     0.1509   3.877 0.000180 ***
SupportsCOG only       1.0668     1.9435   0.549 0.584183
SupportsCOG+AFF       -1.9916     1.9590  -1.017 0.311555
ECT:SupportsCOG only  -0.1993     0.2065  -0.965 0.336647
ECT:SupportsCOG+AFF    0.1078     0.2057   0.524 0.601226
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.129 on 110 degrees of freedom
Multiple R-squared:  0.3093,    Adjusted R-squared:  0.2779
F-statistic: 9.852 on 5 and 110 DF,  p-value: 8.382e-08
```

```
anova(ECTbase,ECTATI)
```

```
Analysis of Variance Table

Model 1: ECTpost ~ ECT + Supports
Model 2: ECTpost ~ ECT * Supports
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1    112 509.71
2    110 498.58  2    11.124 1.2271 0.2971
```

Diagnostic plots

```
oldpar <- par(mfrow=c(2,2)) # Put all of the plot together
plot(ECTbase)
```




```
par(oldpar) # Restore the graphics window
```

Influential points

```
dfb <- dfbetas(ECTbase)
summary(dfb)
```

```
  (Intercept)              ECT             SupportsCOG only
 Min.   :-0.6918712   Min.   :-0.1977376   Min.   :-0.3265859
 1st Qu.:-0.0230543   1st Qu.:-0.0572469   1st Qu.:-0.0352084
 Median : 0.0034389   Median : 0.0003176   Median :-0.0012389
 Mean   :-0.0005849   Mean   : 0.0004359   Mean   : 0.0002644
 3rd Qu.: 0.0517385   3rd Qu.: 0.0240710   3rd Qu.: 0.0142047
 Max.   : 0.2821892   Max.   : 0.4952094   Max.   : 0.3950561
 SupportsCOG+AFF
 Min.   :-0.3489227
 1st Qu.:-0.0377298
 Median : 0.0001959
 Mean   : 0.0000221
 3rd Qu.: 0.0370026
 Max.   : 0.3699555
```

Flagging value is `{r} 2/sqrt(nrow(dfb))`

```
## Calculate a logical value rows higer than flagged value.
flags <- apply(dfb,1,function(r) any(r>2/sqrt(nrow(dfb))))
PPIESExtract$StudyID[flags]
```

```
 [1] "C0066" "A0594" "F1337" "F1450" "F1562" "F2024" "C2192" "F3069" "C3395"
[10] "A3520" "C3676" "F3733"
```

```
dfb[flags,]
```

```
    (Intercept)         ECT SupportsCOG only SupportsCOG+AFF
4    0.03654101 -0.04082561      0.001963686     0.237167321
25  -0.16751897  0.18716130     -0.157136503    -0.015609607
45   0.18985529 -0.13588964     -0.108406731    -0.101518909
51  -0.69187121  0.49520945      0.395056137     0.369955513
54  -0.01193039 -0.13772952      0.234406729     0.235126049
61  -0.45887962  0.32844483      0.262018721     0.245370876
```

```
67  -0.16829815  0.18803184     -0.009044211    -0.162849806
85  -0.01542288 -0.17804828      0.303026650     0.303956542
99   0.15304974 -0.17099549      0.008224774     0.202169254
104  0.08266226 -0.09235477      0.193952491     0.007702563
109 -0.36950320  0.41282907     -0.019856814    -0.207837518
112  0.28218916 -0.09564341     -0.326585876    -0.317185830
```

Remove flagged values

```
ECTnoinf <- lm(ECTpost ~ ECT + Supports, data=PPIESExtract,
               subset = !flags)
summary(ECTnoinf)
```

```
Call:
lm(formula = ECTpost ~ ECT + Supports, data = PPIESExtract, subset = !flags)

Residuals:
    Min      1Q  Median      3Q     Max
-6.4911 -1.0138  0.1497  1.2870  3.3210

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)      6.59967    0.78814   8.374 3.55e-13 ***
ECT              0.47733    0.07664   6.228 1.12e-08 ***
SupportsCOG only -1.21658    0.43406  -2.803  0.00609 **
SupportsCOG+AFF  -1.40449    0.44773  -3.137  0.00224 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.751 on 100 degrees of freedom
Multiple R-squared:  0.3228,    Adjusted R-squared:  0.3025
F-statistic: 15.89 on 3 and 100 DF,  p-value: 1.596e-08
```

```
rbind(base=coef(ECTbase),
      noinf=coef(ECTnoinf))
```

```
      (Intercept)       ECT SupportsCOG only SupportsCOG+AFF
base     5.454182 0.5540946       -0.7688248      -0.9542281
noinf    6.599668 0.4773266       -1.2165801      -1.4044902
```

Exploring more models

```
ECTminmod <- ECTpost ~ ECT + Supports
ECTmaxmod <- ECTpost ~ ECT + Supports + Age + Sex + White + Gaming +
  Physics + POT + gold + silver + quit
ECTstep <- step(ECTbase,list(lower=ECTminmod,upper=ECTmaxmod),trace=2)
```

```
Start:  AIC=179.71
ECTpost ~ ECT + Supports

          Df Sum of Sq    RSS    AIC
+ gold     1    38.091 471.61 172.70
+ POT      1    27.882 481.82 175.18
+ White    1    26.161 483.54 175.60
+ Physics  1    18.944 490.76 177.31
+ quit     1    12.241 497.46 178.89
+ Sex      1    10.103 499.60 179.39
<none>                509.71 179.71
+ silver   1     0.415 509.29 181.61
+ Age      1     0.022 509.68 181.70
+ Gaming   4    22.859 486.85 182.38

Step:  AIC=172.7
ECTpost ~ ECT + Supports + gold

          Df Sum of Sq    RSS    AIC
+ quit     1    18.219 453.40 170.13
+ POT      1    17.647 453.97 170.28
+ Physics  1    15.385 456.23 170.85
+ White    1    12.700 458.91 171.53
<none>                471.61 172.70
+ Sex      1     5.590 466.03 173.31
+ silver   1     1.347 470.27 174.37
+ Age      1     1.036 470.58 174.44
+ Gaming   4    23.170 448.45 174.85
- gold     1    38.091 509.71 179.71

Step:  AIC=170.13
ECTpost ~ ECT + Supports + gold + quit

          Df Sum of Sq    RSS    AIC
```

```
+ POT      1    18.818 434.58 167.21
+ White    1    16.188 437.21 167.91
+ Physics  1    15.880 437.52 167.99
+ Gaming   4    36.055 417.34 168.52
+ Sex      1    10.055 443.34 169.53
<none>                 453.40 170.13
+ Age      1     0.573 452.82 171.98
+ silver   1     0.271 453.13 172.06
- quit     1    18.219 471.61 172.70
- gold     1    44.069 497.46 178.89

Step:  AIC=167.21
ECTpost ~ ECT + Supports + gold + quit + POT

          Df Sum of Sq    RSS    AIC
+ White    1    18.395 416.18 164.19
+ Physics  1    15.375 419.20 165.03
+ Gaming   4    30.277 404.30 166.83
<none>                 434.58 167.21
+ Sex      1     5.782 428.80 167.66
+ Age      1     0.238 434.34 169.15
+ silver   1     0.123 434.45 169.18
- POT      1    18.818 453.40 170.13
- quit     1    19.390 453.97 170.28
- gold     1    32.919 467.50 173.68

Step:  AIC=164.19
ECTpost ~ ECT + Supports + gold + quit + POT + White

          Df Sum of Sq    RSS    AIC
+ Gaming   4    32.595 383.59 162.73
+ Physics  1    11.473 404.71 162.95
<none>                 416.18 164.19
+ Sex      1     5.577 410.61 164.63
+ silver   1     0.727 415.46 165.99
+ Age      1     0.412 415.77 166.08
- White    1    18.395 434.58 167.21
- gold     1    19.178 435.36 167.42
- POT      1    21.024 437.21 167.91
- quit     1    23.312 439.50 168.52

Step:  AIC=162.73
ECTpost ~ ECT + Supports + gold + quit + POT + White + Gaming
```

```
          Df Sum of Sq    RSS    AIC
+ Physics  1    10.713 372.88 161.45
<none>                383.59 162.73
+ silver   1     2.090 381.50 164.10
- Gaming   4    32.595 416.18 164.19
+ Age      1     0.268 383.32 164.65
- POT      1    13.282 396.87 164.68
+ Sex      1     0.043 383.55 164.72
- gold     1    20.042 403.63 166.64
- White    1    20.712 404.30 166.83
- quit     1    37.136 420.72 171.45

Step:  AIC=161.45
ECTpost ~ ECT + Supports + gold + quit + POT + White + Gaming +
    Physics

          Df Sum of Sq    RSS    AIC
<none>                372.88 161.45
- Physics  1    10.713 383.59 162.73
- Gaming   4    31.835 404.71 162.95
+ silver   1     0.964 371.91 163.15
+ Age      1     0.934 371.94 163.16
- POT      1    12.321 385.20 163.22
+ Sex      1     0.029 372.85 163.44
- White    1    17.092 389.97 164.65
- gold     1    19.459 392.33 165.35
- quit     1    36.969 409.84 170.41
```

```
summary(ECTstep)
```

```
Call:
lm(formula = ECTpost ~ ECT + Supports + gold + quit + POT + White +
    Gaming + Physics, data = PPIESExtract)

Residuals:
    Min      1Q  Median      3Q     Max
-4.5265 -1.3610  0.4432  1.3402  3.3360

Coefficients:
```

```
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                   3.25129    1.03860   3.130  0.00227 **
ECT                           0.37062    0.08926   4.152 6.81e-05 ***
SupportsCOG only             -0.42316    0.45531  -0.929  0.35486
SupportsCOG+AFF              -0.99902    0.46812  -2.134  0.03521 *
gold                          0.14001    0.06039   2.318  0.02240 *
quit                          0.11807    0.03695   3.196  0.00185 **
POT                           0.19227    0.10422   1.845  0.06794 .
WhiteTRUE                     1.04390    0.48042   2.173  0.03208 *
GamingOnce a month or less -1.09580    0.67756  -1.617  0.10887
GamingOnce a week          -0.75415    0.75671  -0.997  0.32128
Gaming3-4 times a week      0.16173    0.63180   0.256  0.79847
GamingEvery day             0.44679    0.64883   0.689  0.49262
PhysicsNo                  -0.71581    0.41611  -1.720  0.08839 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.903 on 103 degrees of freedom
Multiple R-squared:  0.4835,    Adjusted R-squared:  0.4233
F-statistic: 8.033 on 12 and 103 DF,  p-value: 1.97e-10
```

Splitting into High and Low initial ECT values

Added the median split variable so that we could fit separate slopes to high and low ECT values.

```r
ECThighlow <- lm(ECTpost ~ ECT*LowECT + Supports*LowECT,data=PPIESExtract)
summary(ECThighlow)
```

```
Call:
lm(formula = ECTpost ~ ECT * LowECT + Supports * LowECT, data = PPIESExtract)

Residuals:
    Min      1Q  Median      3Q     Max
-7.4465 -1.2895  0.3619  1.3619  4.0063

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                 9.3072     1.7640   5.276 6.85e-07 ***
ECT                         0.1917     0.1616   1.186 0.238112
```

```
LowECTTRUE                    -9.4533     2.5684  -3.681 0.000365 ***
SupportsCOG only              -0.8725     0.6002  -1.454 0.148968
SupportsCOG+AFF               -0.5857     0.5950  -0.984 0.327193
ECT:LowECTTRUE                 1.2645     0.3298   3.834 0.000213 ***
LowECTTRUE:SupportsCOG only   -0.3410     0.9924  -0.344 0.731836
LowECTTRUE:SupportsCOG+AFF    -1.4674     1.0127  -1.449 0.150226
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.021 on 108 degrees of freedom
Multiple R-squared:  0.3891,    Adjusted R-squared:  0.3495
F-statistic: 9.825 on 7 and 108 DF,  p-value: 1.97e-09
```

```
anova(ECTbase,ECThighlow)
```

```
Analysis of Variance Table

Model 1: ECTpost ~ ECT + Supports
Model 2: ECTpost ~ ECT * LowECT + Supports * LowECT
  Res.Df    RSS Df Sum of Sq     F   Pr(>F)
1    112 509.71
2    108 441.02  4    68.685 4.205 0.003337 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Logistic Regression

The research question is what is the relationship between game enjoyment and physics ability (as measured by the pretest), `PhysicsScore`

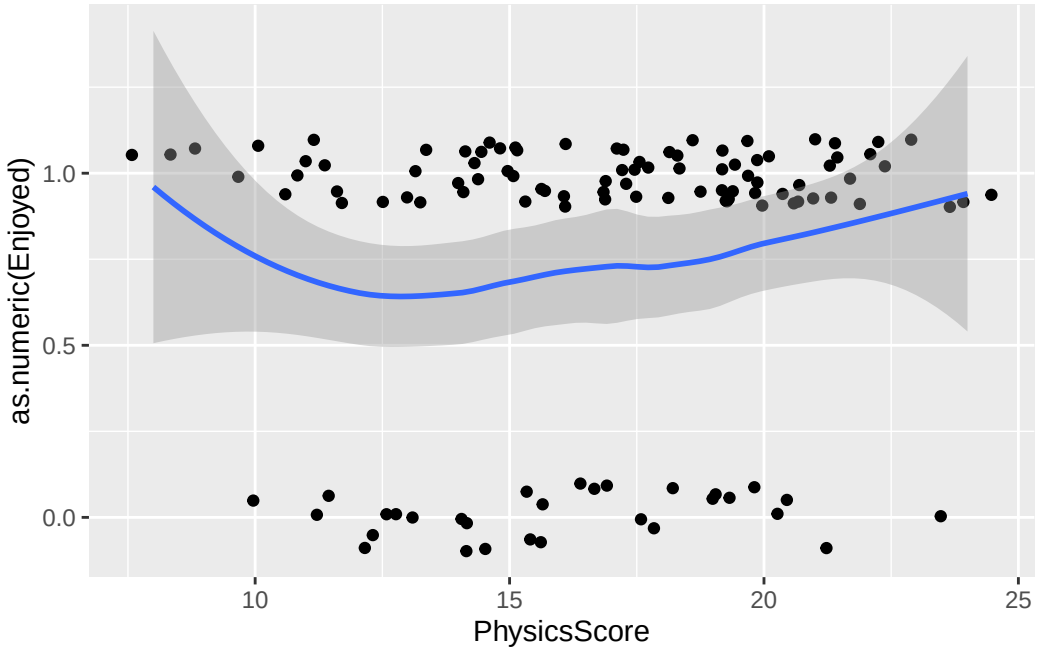
The `IMI_Enj` variables is the sum of two 7-option Likert scale items, so 8 is neutral on both variables. So define enjoyment as `IMI_Enj > 8`.

Also, look at the role of gender.

Exploratory analysis

```
ggplot(PPIESExtract,aes(x=PhysicsScore,y=as.numeric(Enjoyed))) +
  geom_point(position=position_jitter(width=.5,height=.1)) +
  geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Enjoyment by Gender

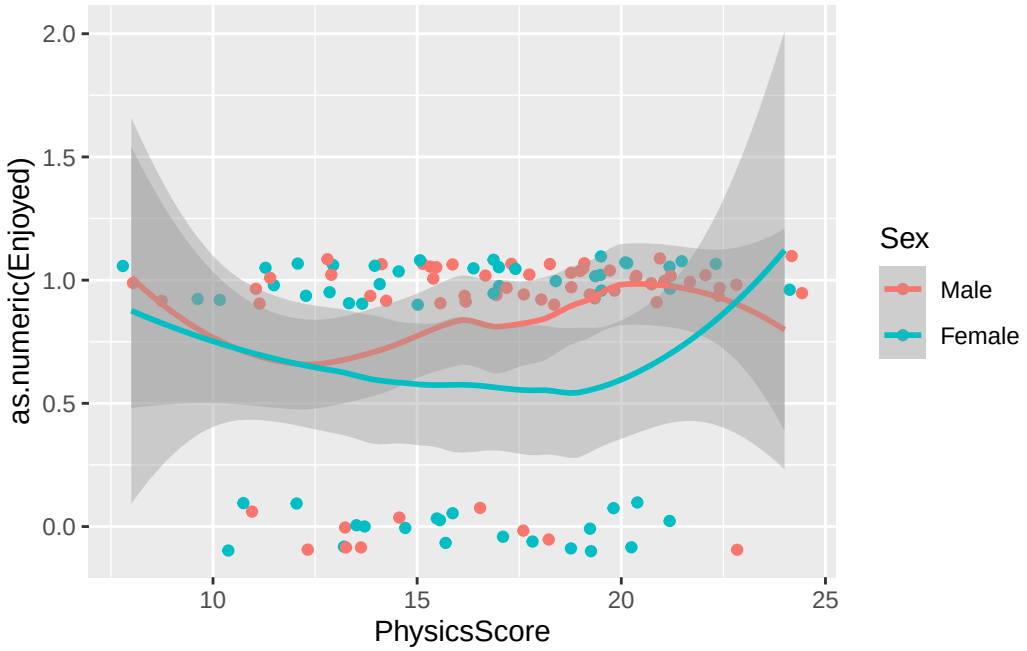
```
table(PPIESExtract$Enjoyed,PPIESExtract$Sex)
```

```
       Male Female Other Prefer not to say Nonbinary
FALSE    10     20     0                 0         0
TRUE     52     34     0                 0         0
```

All three variables together

```
ggplot(PPIESExtract,aes(x=PhysicsScore,y=as.numeric(Enjoyed),color=Sex)) +
  geom_point(position=position_jitter(width=.5,height=.1)) +
  geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Base Model

```
ENJphys <- glm(Enjoyed ~ PhysicsCenter, data=PPIESExtract,
               family=binomial())
summary(ENJphys)
```

```
Call:
glm(formula = Enjoyed ~ PhysicsCenter, family = binomial(), data = PPIESExtract)

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    1.07145    0.21543   4.973 6.58e-07 ***
```

```
PhysicsCenter  0.07384    0.05670   1.302    0.193
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 132.61  on 115  degrees of freedom
Residual deviance: 130.90  on 114  degrees of freedom
AIC: 134.9

Number of Fisher Scoring iterations: 4
```

Prediction at mean physics ability

```
round(psych::logistic(coef(ENJphys)[1]),2)
```

```
(Intercept)
       0.74
```

Model with gender

```
ENJphysG <- glm(Enjoyed ~ PhysicsCenter + Sex, data=PPIESExtract,
                family=binomial())
summary(ENJphysG)
```

```
Call:
glm(formula = Enjoyed ~ PhysicsCenter + Sex, family = binomial(),
    data = PPIESExtract)

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)   1.63383    0.34640   4.717  2.4e-06 ***
PhysicsCenter 0.05651    0.05889   0.960   0.3373
SexFemale    -1.06317    0.44989  -2.363   0.0181 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)
```

```
    Null deviance: 132.61  on 115  degrees of freedom
Residual deviance: 125.05  on 113  degrees of freedom
AIC: 131.05

Number of Fisher Scoring iterations: 4
```

Prediction at mean physics ability

```
round(psych::logistic(coef(ENJphysG)[1]+c(Male=0,Female=1)*coef(ENJphysG)[3]),2)
```

```
  Male Female
  0.84   0.64
```

Model with gender interaction

```
ENJphysXG <- glm(Enjoyed ~ PhysicsCenter * Sex, data=PPIESExtract,
              family=binomial())
summary(ENJphysXG)
```

```
Call:
glm(formula = Enjoyed ~ PhysicsCenter * Sex, family = binomial(),
    data = PPIESExtract)

Coefficients:
                       Estimate Std. Error z value Pr(>|z|)
(Intercept)             1.68015    0.36404   4.615 3.93e-06 ***
PhysicsCenter           0.15656    0.09366   1.672   0.0946 .
SexFemale              -1.15787    0.46245  -2.504   0.0123 *
PhysicsCenter:SexFemale -0.17080    0.12123  -1.409   0.1589
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 132.61  on 115  degrees of freedom
Residual deviance: 123.02  on 112  degrees of freedom
AIC: 131.02
```

```
Number of Fisher Scoring iterations: 4
```

Prediction at mean physics ability

```
round(psych::logistic(coef(ENJphysXG)[1]+c(Male=0,Female=1)*coef(ENJphysXG)[3]),2)
```

```
  Male Female
  0.84   0.63
```

Analysis of Deviance

Like Analysis of Variance, only with Deviance & chi-squared.

```
anova(ENJphys,ENJphysG,ENJphysXG)
```

```
Analysis of Deviance Table

Model 1: Enjoyed ~ PhysicsCenter
Model 2: Enjoyed ~ PhysicsCenter + Sex
Model 3: Enjoyed ~ PhysicsCenter * Sex
  Resid. Df Resid. Dev Df Deviance
1       114     130.90
2       113     125.05  1   5.8513
3       112     123.02  1   2.0272
```

The differences in deviance are chi-squared valued.

Here is a chi-square table.

```
chi2.1.table <- rbind(prob=c(.5,.75,.9,.95,.99),
                      X2=qchisq(c(.5,.75,.9,.95,.99),1))
round(chi2.1.table,2)
```

```
     [,1] [,2] [,3] [,4] [,5]
prob 0.50 0.75 0.90 0.95 0.99
X2   0.45 1.32 2.71 3.84 6.63
```