W241 Project Analysis

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```r
# load packages
library(data.table)
library(foreign)
library(sandwich)
library(lmtest)
```

```
## Loading required package: zoo

## Warning: package 'zoo' was built under R version 3.5.1

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```r
library(AER)
```

```
## Warning: package 'AER' was built under R version 3.5.2

## Loading required package: car

## Warning: package 'car' was built under R version 3.5.1

## Loading required package: carData

## Loading required package: survival

## Warning: package 'survival' was built under R version 3.5.1
```

```r
library(multiwayvcov)                    # for clustered SEs
```

```
## Warning: package 'multiwayvcov' was built under R version 3.5.2
```

```r
library(stargazer)
```

```
## Warning: package 'stargazer' was built under R version 3.5.2

##
## Please cite as:

##  Hlavac, Marek (2018). stargazer: Well-Formatted Regression and Summary Statistics Tables.

##  R package version 5.2.2. https://CRAN.R-project.org/package=stargazer
```

** First Outcome - Daily app usage analysis with clustered standard errors **

```r
# Reading the data and loading into datatable
result <- read.csv(file = './data/result_daily2.csv',
                              header = TRUE,
                              sep = ',',
                              stringsAsFactors = FALSE)
dt_daily0 <- data.table(result)
```

```r
# Filter for rows with daily usage measurements.
dt_daily0 = dt_daily0[Has_Daily=="Yes"]
head(dt_daily0)
```

```
##    ID                     Email Experiment_App Treat Mobile_OS
## 1:  1       Yy360@georgetown.edu      Instagram     0 Apple iOS
## 2:  2  alexander.kho10@gmail.com             FB     1   Android
## 3:  3   anusha.praturu@gmail.com      Instagram     1 Apple iOS
## 4:  4 conor@ischool.berkeley.edu             FB     0 Apple iOS
## 5:  5       cqysunny0426@gwu.edu         WeChat     0   Android
## 6:  6        hesterhql@gmail.com         WeChat     1 Apple iOS
##              Name Age Gender                  Country Has_Daily
## 1:          Yijun  25 Female United States of America       Yes
## 2:  Alexander kho  35   Male                Singapore       Yes
## 3: Anusha Praturu  24 Female United States of America       Yes
## 4:          Conor  41   Male United States of America       Yes
## 5:     Qinyu Chen  23 Female United States of America       Yes
## 6:     Qiaoluo He  31 Female United States of America       Yes
##    activation1 pleasant1 activation7 pleasant7 activation14 pleasant14
## 1:          79       105          52        66          93        122
## 2:          68        78          67        94          66         96
## 3:          98       109          88       104          NA         NA
## 4:         111       113         123       115         110        109
## 5:          97       125         100       127         109        132
## 6:          72        70          26        39          51         72
##    daily_usage_1_old daily_usage_1 daily_usage_7_old daily_usage_7
## 1:             19.14         21.63             17.17         17.17
## 2:              0.71          0.80              3.67          3.67
## 3:             72.29         79.19             75.14         81.18
## 4:             10.83         10.83              3.83          3.83
## 5:             73.57         78.02            117.57        130.78
## 6:             93.00         93.00             85.00         90.70
##    daily_usage_14_old daily_usage_14 Day Week0 Day1_1 Day1_2 Day1_3 Day1_4
## 1:              31.71          36.79   1  0.00   0.00  33.50  37.52  42.66
## 2:               4.86           5.67   1  2.56   2.56   0.51   0.00   0.00
## 3:              60.67          60.67   1 47.27  47.27 114.18  71.71  59.69
## 4:               2.71           2.57   1 13.99  13.99   4.57   5.22  17.63
## 5:              74.43          78.07   1 52.42  52.42  48.22  67.36  79.94
## 6:             132.17         132.04   1 93.00  93.00  93.00  93.00  93.00
##    Day1_5 Day1_6  Week1 Day7_1 Day7_2 Day7_3 Day7_4 Day7_5 Day7_6  Week2
## 1:  13.62   2.46  44.11  44.11  23.09  17.32   7.16  11.09   0.23  61.67
## 2:   1.28   0.45   0.66   0.66   0.84   2.04   6.08  12.06   0.33   0.00
## 3:  72.51 109.77  36.71  36.71  32.88 156.70 121.64  51.50  87.67  71.34
## 4:   7.74  15.85   6.97   6.97   0.91   2.67   2.74   3.69   6.02   0.53
## 5: 116.89 103.26 141.83 141.83 133.36 122.68 141.46 163.94  81.42  22.41
## 6:  93.00  93.00 120.69 120.69  79.19 111.38  69.45  96.13  67.33 144.46
##    Day14_1 Day14_2 Day14_3 Day14_4 Day14_5 Day14_6
## 1:   61.67   17.53   31.48   16.88   42.19   50.96
## 2:    0.00   22.54    0.00    0.00    8.32    3.14
## 3:   71.34   80.12   27.07  104.26   71.34    9.88
## 4:    0.53    0.40    4.94    1.15    8.38    0.00
## 5:   22.41   86.88   99.05  123.13   68.06   68.89
## 6:  144.46  218.23   73.77  119.10   99.89  136.78
```

```
# Defining a function for cluster robust standard errors

run_ttestCls <- function(model, variable_list, cls){

  ## function that calculates Clustered SEs for a linear model
  ## and provides the t-test of coefficients and calculates the
  ## 95% confidence interval

  model_x_coeff <- model$coefficients

  cat("\n")
  cat("Using Clustered SE:\n")

  vcovCls <- cluster.vcov(model=model, cluster=cls)
  se_model <- sqrt(diag(vcovCls))

  print(coeftest(model, vcov=vcovCls))

  for (variable in variable_list) {
    cat("95% confidence interval of coeff. of",variable,":\n")
    cat(model_x_coeff[variable]-1.96*se_model[variable],
        model_x_coeff[variable]+1.96*se_model[variable],"\n")
    cat("\n")
  }

  return(se_model)
}
```

** General Model**

```
# Linear model to see if Treatment of sending messages affects average daily app usage post-treatment D
model_week1 <- dt_daily0[, lm(Week1 ~  Week0 + Treat)]
model_week2 <- dt_daily0[, lm(Week2 ~  Week0 + Treat)]
summary(model_week1)
```

```
##
## Call:
## lm(formula = Week1 ~ Week0 + Treat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -102.281  -16.483   -6.023   12.511   99.225
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.47560    6.53899   1.143    0.256
## Week0        0.89013    0.07461  11.931   <2e-16 ***
## Treat       -2.62504    7.65525  -0.343    0.732
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 35.12 on 87 degrees of freedom
## Multiple R-squared:  0.6248, Adjusted R-squared:  0.6162
## F-statistic: 72.44 on 2 and 87 DF,  p-value: < 2.2e-16
```

```r
summary(model_week2)
```

```
##
## Call:
## lm(formula = Week2 ~ Week0 + Treat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -100.410  -15.087   -4.721   16.477  130.447
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.13717    6.37764   0.335    0.738
## Week0        0.79295    0.07276  10.897   <2e-16 ***
## Treat       11.90102    7.46635   1.594    0.115
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 34.25 on 87 degrees of freedom
## Multiple R-squared:  0.5995, Adjusted R-squared:  0.5903
## F-statistic: 65.11 on 2 and 87 DF,  p-value: < 2.2e-16
```

```r
# Adding clustered standard errors, clustering on ID
num_clusters <- nrow(dt_daily0[, .N, by=.(ID)])

model_week1.se <- run_ttestCls(model_week1, c("Week0","Treat"), dt_daily0[, ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##              Estimate Std. Error t value  Pr(>|t|)
## (Intercept)  7.475597   9.966652  0.7501    0.4552
## Week0        0.890130   0.099443  8.9511 5.655e-14 ***
## Treat       -2.625039  11.958541 -0.2195    0.8268
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## 0.6952213 1.085039
##
## 95% confidence interval of coeff. of Treat :
## -26.06378 20.8137
```

```r
model_week2.se <- run_ttestCls(model_week2, c("Week0","Treat"), dt_daily0[, ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)  2.13717    6.76549  0.3159    0.7528
## Week0        0.79295    0.10151  7.8119 1.192e-11 ***
## Treat        11.90102    8.19217  1.4527    0.1499
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## 0.5939982 0.9919013
##
## 95% confidence interval of coeff. of Treat :
## -4.155629 27.95767
```

```
# Stargazer table for daily app usage, generic model, cls errors

stargazer(model_week1, model_week2,
          #type="text",
          type="latex",
          se = list(model_week1.se, model_week2.se),
          title = "Summary of Outcomes on Daily App Usage",
          header = F,
          font.size = "small",
          dep.var.caption = c("Daily Social Media Usage (minutes)"),
          dep.var.labels = c("during Week-1", "during Week-2"),
          covariate.labels = c("Usage during Week-0 (minutes)", "Treatment during Week-1"),
          star.cutoffs = c(0.1, 0.05, 0.01),
          add.lines = list(c("Clustered SE on Subject", "Yes","Yes"),
                           c("No. of Clusters", num_clusters, num_clusters))
)
```

Table 2: Summary of Outcomes on Daily App Usage

	Daily Social Media Usage (minutes)	
	during Week-1	during Week-2
	(1)	(2)
Usage during Week-0 (minutes)	0.890***	0.793***
	(0.099)	(0.102)
Treatment during Week-1	−2.625	11.901
	(11.959)	(8.192)
Constant	7.476	2.137
	(9.967)	(6.765)
Clustered SE on Subject	Yes	Yes
No. of Clusters	15	15
Observations	90	90
R^2	0.625	0.599
Adjusted R^2	0.616	0.590
Residual Std. Error (df = 87)	35.117	34.251
F Statistic (df = 2; 87)	72.445***	65.113***
Note:	*p<0.1; **p<0.05; ***p<0.01	

** App Specific Model**

```
# Linear model to see if Treatment of sending messages affects average daily app usage post-treatment D
model_week1_FB <- dt_daily0[Experiment_App=="FB", lm(Week1 ~  Week0 + Treat)]
```

```r
model_week2_FB <- dt_daily0[Experiment_App=="FB", lm(Week2 ~  Week0 + Treat)]
model_week1_FB.se <- run_ttestCls(model_week1_FB, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="FB", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.581022   1.692126  3.2982 0.003424 **
## Week0        0.032811   0.094969  0.3455 0.733161
## Treat       -0.608659   2.353077 -0.2587 0.798412
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## -0.1533282 0.2189504
##
## 95% confidence interval of coeff. of Treat :
## -5.220691 4.003372
```

```r
model_week2_FB.se <- run_ttestCls(model_week2_FB, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="FB", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.576801   1.720114  3.2421 0.003902 **
## Week0       -0.101752   0.071556 -1.4220 0.169713
## Treat        4.305302   4.115126  1.0462 0.307356
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## -0.2420023 0.03849809
##
## 95% confidence interval of coeff. of Treat :
## -3.760344 12.37095
```

```r
model_week1_IG <- dt_daily0[Experiment_App=="Instagram", lm(Week1 ~  Week0 + Treat)]
model_week2_IG <- dt_daily0[Experiment_App=="Instagram", lm(Week2 ~  Week0 + Treat)]
model_week1_IG.se <- run_ttestCls(model_week1_IG, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="Instagram", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##              Estimate Std. Error t value  Pr(>|t|)
## (Intercept) -1.22833    6.06782 -0.2024    0.8408
## Week0        0.65112    0.12922  5.0389 1.645e-05 ***
## Treat       11.51503    7.53796  1.5276    0.1361
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## 0.3978485 0.904389
##
## 95% confidence interval of coeff. of Treat :
## -3.259363 26.28943
```

```
model_week2_IG.se <- run_ttestCls(model_week2_IG, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="Instagram", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 16.71637   12.33710  1.3550   0.1846
## Week0        0.33461    0.14646  2.2846   0.0289 *
## Treat        0.23860   12.54093  0.0190   0.9849
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## 0.04753704 0.6216766
##
## 95% confidence interval of coeff. of Treat :
## -24.34162 24.81883
```

```
model_week1_WC <- dt_daily0[Experiment_App=="WeChat", lm(Week1 ~  Week0 + Treat)]
model_week2_WC <- dt_daily0[Experiment_App=="WeChat", lm(Week2 ~  Week0 + Treat)]
model_week1_WC.se <- run_ttestCls(model_week1_WC, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="WeChat", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 69.69845   36.45375  1.9120  0.06655 .
## Week0        0.41873    0.28946  1.4466  0.15953
## Treat        0.94993   24.35043  0.0390  0.96917
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## -0.1486178 0.9860828
##
## 95% confidence interval of coeff. of Treat :
## -46.77692 48.67678
```

```
model_week2_WC.se <- run_ttestCls(model_week2_WC, c("Week0","Treat"),
                                  dt_daily0[Experiment_App=="WeChat", ID])
```

```
##
## Using Clustered SE:
##
## t test of coefficients:
##
##              Estimate Std. Error t value  Pr(>|t|)
## (Intercept) 52.37025   19.91788  2.6293   0.01395 *
## Week0        0.19949    0.23894  0.8349   0.41111
## Treat       56.99072    9.55031  5.9674 2.305e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 95% confidence interval of coeff. of Week0 :
## -0.2688419 0.6678209
##
## 95% confidence interval of coeff. of Treat :
## 38.27212 75.70932
```

```
num_clusters_FB <- nrow(dt_daily0[Experiment_App=="FB", .N, by=.(ID)])
num_clusters_IG <- nrow(dt_daily0[Experiment_App=="Instagram", .N, by=.(ID)])
num_clusters_WC <- nrow(dt_daily0[Experiment_App=="WeChat", .N, by=.(ID)])
```

```
# Stargazer table for daily app usage, app specific model, cls errors

stargazer(model_week1_FB, model_week1_IG, model_week1_WC,
          model_week2_FB, model_week2_IG, model_week2_WC,
          #type="text",
          type="latex",
          se = list(model_week1_FB.se, model_week1_IG.se, model_week1_WC.se,
                    model_week2_FB.se, model_week2_IG.se, model_week2_WC.se),
          title = "Summary of Outcomes on Daily App Usage, Segregated on the Different Apps",
          header = F,
          font.size = "small",
          float = FALSE,
          float.env = "sidewaystable",
          dep.var.caption = c("Daily Social Media Usage (minutes)"),
          dep.var.labels = c("during Week-1", "during Week-2"),
          column.labels = c("Facebook", "Instagram", "WeChat", "Facebook", "Instagram", "WeChat"),
          column.separate = c(1,1,1,1,1,1),
          covariate.labels = c("Usage during Week-0\\\\ (minutes)", "Treatment during Week-1"),
          star.cutoffs = c(0.1, 0.05, 0.01),
          add.lines = list(c("Clustered SE on Subject", "Yes", "Yes", "Yes", "Yes", "Yes", "Yes"),
                           c("No. of Clusters", num_clusters_FB, num_clusters_IG, num_clusters_WC,
                             num_clusters_FB, num_clusters_IG, num_clusters_WC))
)
```

	Daily Social Media Usage (minutes)					
	during Week-1			during Week-2		
	Facebook	Instagram	WeChat	Facebook	Instagram	WeChat
	(1)	(2)	(3)	(4)	(5)	(6)
Usage during Week-0 (minutes)	0.033	0.651^{***}	0.419	−0.102	0.335^{**}	0.199
	(0.095)	(0.129)	(0.289)	(0.072)	(0.146)	(0.239)
Treatment during Week-1	−0.609	11.515	0.950	4.305	0.239	56.991^{***}
	(2.353)	(7.538)	(24.350)	(4.115)	(12.541)	(9.550)
Constant	5.581^{***}	−1.228	69.698^{*}	5.577^{***}	16.716	52.370^{***}
	(1.692)	(6.068)	(36.454)	(1.720)	(12.337)	(19.918)
Clustered SE on Subject	Yes	Yes	Yes	Yes	Yes	Yes
No. of Clusters	4	6	5	4	6	5
Observations	24	36	30	24	36	30
R^2	0.007	0.404	0.169	0.071	0.187	0.477
Adjusted R^2	−0.088	0.368	0.108	−0.017	0.137	0.438
Residual Std. Error	8.034 (df = 21)	27.205 (df = 33)	42.255 (df = 27)	10.302 (df = 21)	23.600 (df = 33)	36.562 (df = 27)
F Statistic	0.073 (df = 2; 21)	11.206^{***} (df = 2; 33)	2.753^{*} (df = 2; 27)	0.805 (df = 2; 21)	3.788^{**} (df = 2; 33)	12.310^{***} (df = 2; 27)
Note:						*p<0.1; **p<0.05; ***p<0.01

** Previous methodology with data import on averaged daily app usage only **

```r
# Reading the data and loading into datatable
result <- read.csv(file = './data/result.csv',
                              header = TRUE,
                              sep = ',',
                              stringsAsFactors = FALSE)
dt0 <- data.table(result)
```

```r
# Adding delta fields for daily_usage, activation and pleasant
dt0[, "d_daily_usage":= daily_usage_7 - daily_usage_1 ]
dt0[, "d2_daily_usage":= daily_usage_14 - daily_usage_1 ]
dt0[, "pct_ch_daily_usage":= ((daily_usage_7 / daily_usage_1) - 1)*100]
dt0[, "pct_ch2_daily_usage":= ((daily_usage_14 / daily_usage_1) - 1)*100]
dt0[, "d_activation" := activation7 - activation1 ]
dt0[, "d_pleasant"   := pleasant7 - pleasant1 ]

# Adding dummy variables for FB, Instagram, and WeChat
dt0[Experiment_App == "FB", "App_FB":= 1 ]
dt0[Experiment_App != "FB", "App_FB":= 0 ]
dt0[Experiment_App == "Instagram", "App_IG":= 1 ]
dt0[Experiment_App != "Instagram", "App_IG":= 0 ]
dt0[,"Age_under_30":= 0]
dt0[Age < 30, "Age_under_30":= 1]
dt0[,"Female":= 0]
dt0[Gender == "Female", "Female":= 1]
dt0[,"USA":= 0]
dt0[Country == "United States of America", "USA":= 1]
dt0[,"Android":= 0]
dt0[Mobile_OS == "Android", "Android":= 1]
```

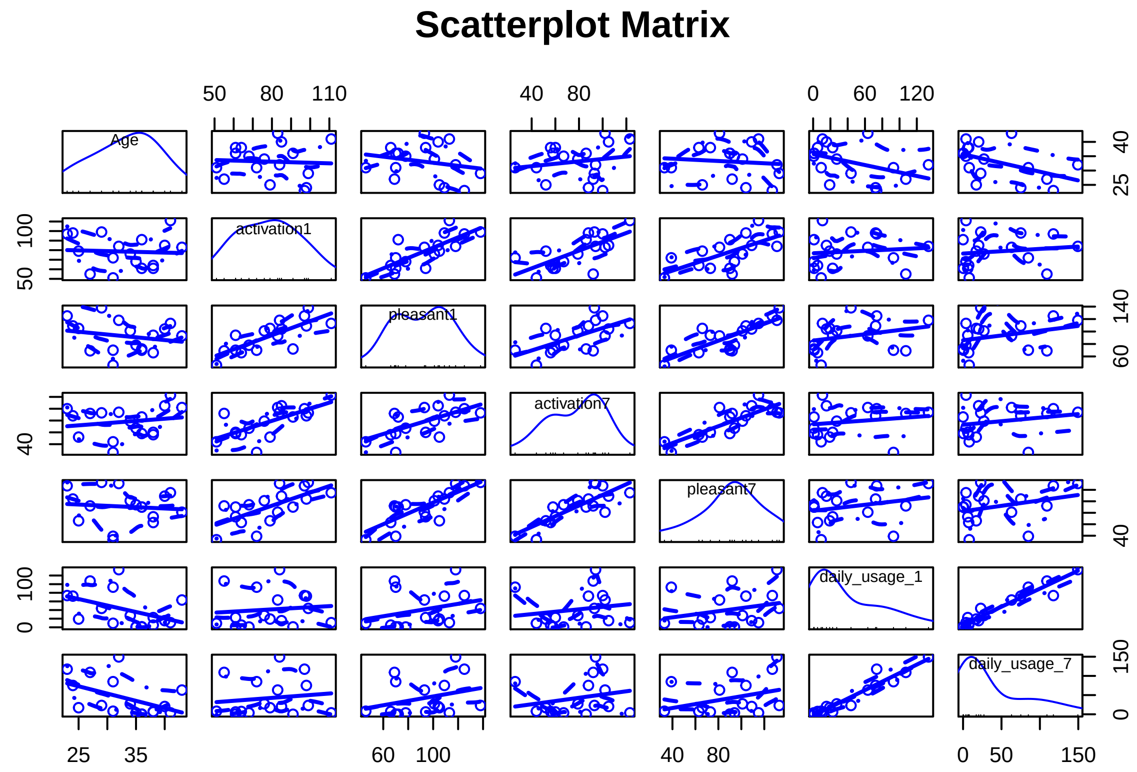
```r
# Extract out only data from day 1 to Day 7 to reduce attrition
dt1 <- copy(dt0)
dt1[,c("activation14", "pleasant14", "daily_usage_14", "d2_daily_usage", "pct_ch2_daily_usage"):=NULL]

dt1 <- data.table(na.omit(dt1))
cat("From Day 1 up to Day 7: \n Total number of unattritted subjects:",nrow(dt1))
```

```
## From Day 1 up to Day 7:
##  Total number of unattritted subjects: 17
```

```r
# Total data with full fields
dt1[, .("Total"=.N), by=.(Experiment_App, Treat)][order(Experiment_App, Treat)]
```

```
##    Experiment_App Treat Total
## 1:             FB     0     3
## 2:             FB     1     3
## 3:      Instagram     0     2
## 4:      Instagram     1     4
## 5:         WeChat     0     2
## 6:         WeChat     1     3
```

```r
scatterplotMatrix(~ Age + activation1 + pleasant1 + activation7 + pleasant7 +
                  daily_usage_1 + daily_usage_7, data=dt1,
                  main="Scatterplot Matrix")
```



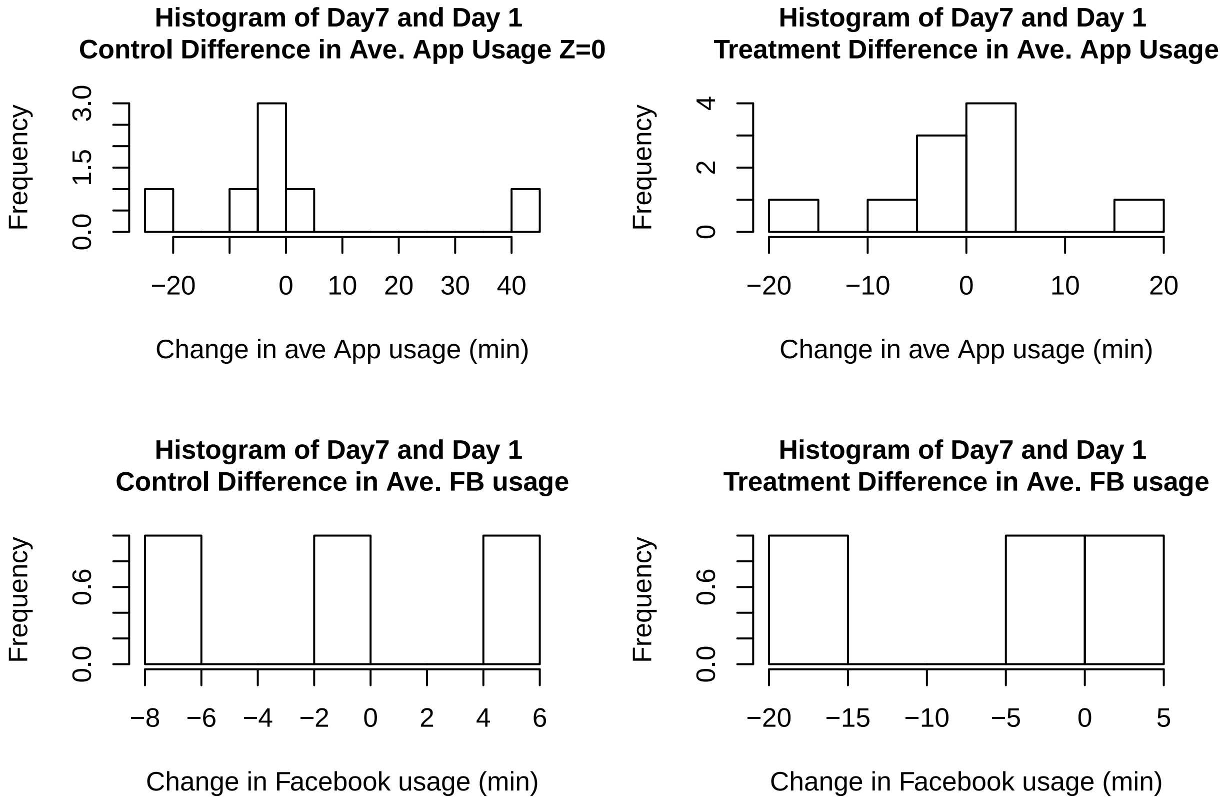
```r
# Covariate Balance Check
# Check Age between Treatment and Control
t.test(dt1[Treat==1,Age], dt1[Treat==0, Age])
```

```
##
##  Welch Two Sample t-test
##
## data:  dt1[Treat == 1, Age] and dt1[Treat == 0, Age]
## t = -0.012575, df = 8.7587, p-value = 0.9902
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -7.784816  7.699102
## sample estimates:
## mean of x mean of y
##  33.10000  33.14286
```

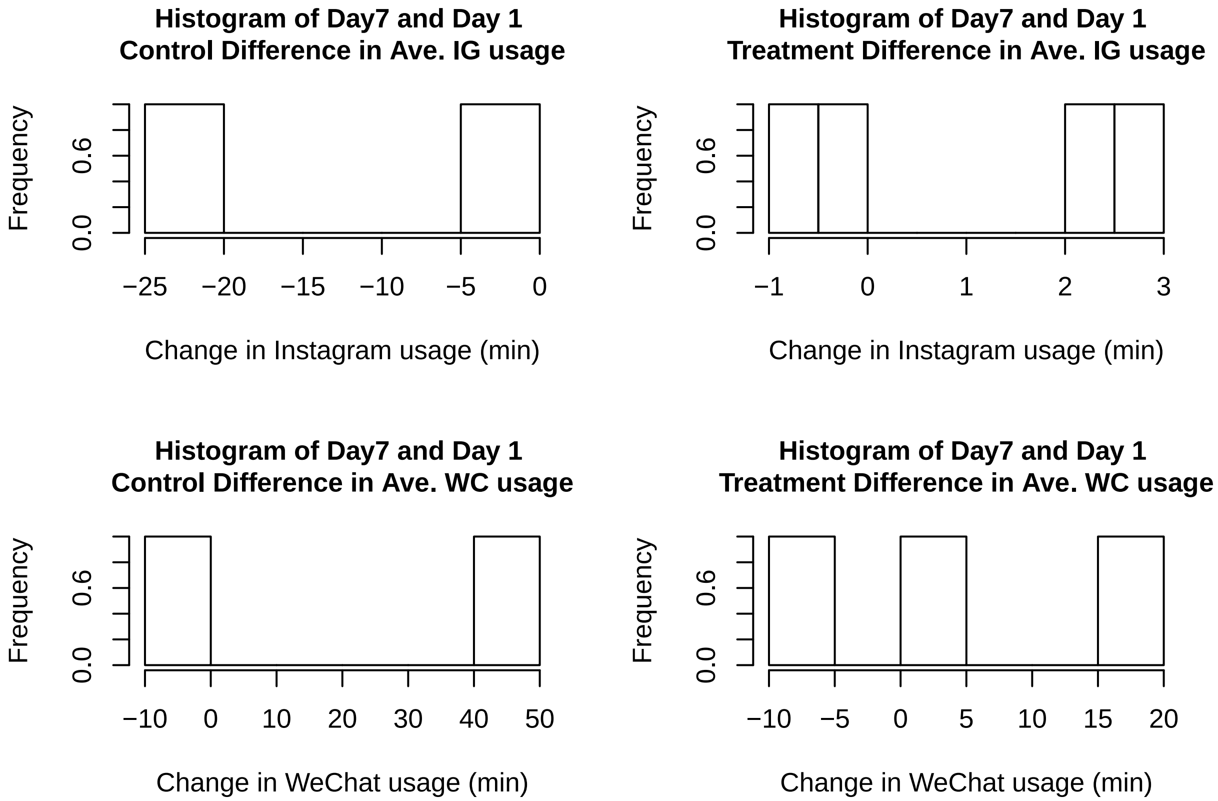
```r
# Check Gender between Treatment and Control
gender <- c(dt1[Gender=='Male',.N], dt1[Gender=='Female',.N])
chisq.test(gender, p = c(1/2, 1/2))
```

```
##
##  Chi-squared test for given probabilities
##
## data:  gender
## X-squared = 0.058824, df = 1, p-value = 0.8084
```

```
# New version of Histograms with difference in daily usage instead of percentage change
par(mfrow=c(2,2))
hist(dt1[Treat==0,d_daily_usage], breaks=10,
     main="Histogram of Day7 and Day 1
Control Difference in Ave. App Usage Z=0", cex.main=1,
     xlab="Change in ave App usage (min)")
hist(dt1[Treat==1,d_daily_usage], breaks=10,
     main="Histogram of Day7 and Day 1
Treatment Difference in Ave. App Usage", cex.main=1,
     xlab="Change in ave App usage (min)")
hist(dt1[Treat==0 & App_FB==1,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Control Difference in Ave. FB usage", cex.main=1,
     xlab="Change in Facebook usage (min)")
hist(dt1[Treat==1 & App_FB==1,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Treatment Difference in Ave. FB usage", cex.main=1,
     xlab="Change in Facebook usage (min)")
```

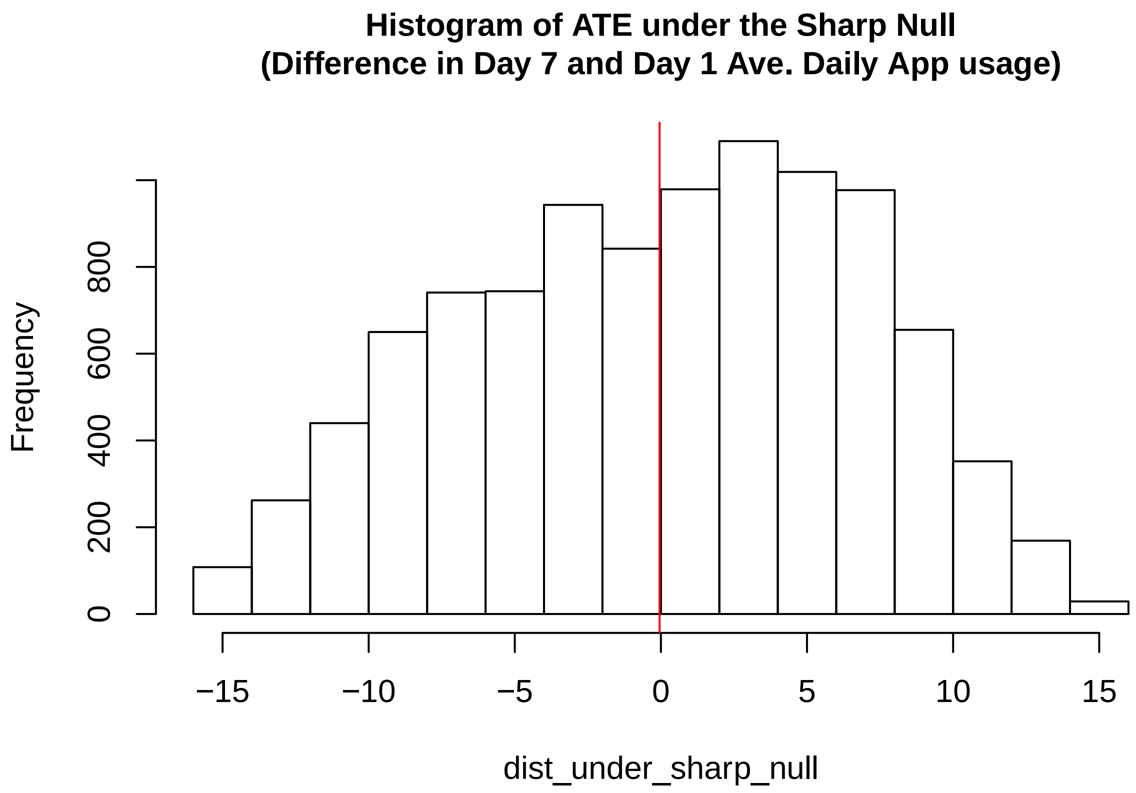


```
par(mfrow=c(2,2))
hist(dt1[Treat==0 & App_IG==1,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Control Difference in Ave. IG usage", cex.main=1,
     xlab="Change in Instagram usage (min)")
hist(dt1[Treat==1 & App_IG==1,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Treatment Difference in Ave. IG usage", cex.main=1,
     xlab="Change in Instagram usage (min)")
hist(dt1[Treat==0 & App_IG==0 & App_FB==0,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Control Difference in Ave. WC usage", cex.main=1,
     xlab="Change in WeChat usage (min)")
hist(dt1[Treat==1 & App_IG==0 & App_FB==0,d_daily_usage], breaks=5,
     main="Histogram of Day7 and Day 1
Treatment Difference in Ave. WC usage", cex.main=1,
     xlab="Change in WeChat usage (min)")
```



Note: No discernable trends between treatment and control

```
# Sharp Null Hypothesis Analysis
# Assuming that treatment has no effect on difference in ave daily usage on Day 7

num_0 <- dt1[Treat==0,.N]
num_1 <- dt1[Treat==1,.N]

# Generate a random treatment vector
randomize <- function(n_0,n_1) {
  sample(c(rep(0, n_0), rep(1, n_1)))
}

# Calculate the average treatment effect
est_ate <- function(outcome, treat) {
  mean(outcome[treat == 1]) - mean(outcome[treat == 0])
}

# Setting the outcome variable : difference in Day 7 and Day 1 ave daily usage
outcome_v <- dt1[, d_daily_usage]

ate_d_ch <- dt1[Treat==1, mean(d_daily_usage)]

# Replicate 10,000 times to get the sample distribution under sharp null
dist_under_sharp_null = replicate(10000, est_ate(outcome_v, randomize(num_0,num_1)))

# Plotting histogram and density plot
hist(dist_under_sharp_null,
     main = "Histogram of ATE under the Sharp Null
(Difference in Day 7 and Day 1 Ave. Daily App usage)",
     cex.main = 1)
abline(v=ate_d_ch, col="red")
```



```
# Reporting results of the sharp null hypothesis

two_tail_p_sharp_null <- length(dist_under_sharp_null[abs(dist_under_sharp_null) >= abs(ate_d_ch)]) /
  length(dist_under_sharp_null)

cat("The two-tailed p-value is", two_tail_p_sharp_null)
```

```
## The two-tailed p-value is 0.9961
```

```
if (two_tail_p_sharp_null < 0.05) {
  cat("\np < 0.05, hence we reject the sharp null hypothesis.")
} else {
  cat("\np >= 0.05, hence we fail to reject the sharp null hypothesis.")
}
```

```
##
## p >= 0.05, hence we fail to reject the sharp null hypothesis.
```

** Second Outcome - “Activation” and “Pleasant” emotional state analysis **

```
# Starting with generic mood model

dt_gmood <- na.omit(dt0, cols = c('activation1', 'activation7', 'activation14',
                                  'pleasant1', 'pleasant7','pleasant14'))
m_gmood_act7 <- lm(activation7~activation1 + Treat , data = dt_gmood)
m_gmood_act14 <- lm(activation14~activation1 + Treat , data = dt_gmood)
m_gmood_ple7 <- lm(pleasant7~pleasant1 + Treat , data = dt_gmood)
m_gmood_ple14 <- lm(pleasant14~pleasant1 + Treat , data = dt_gmood)

dt_fb <- dt0[Experiment_App=='FB']
dt_in <- dt0[Experiment_App=='Instagram']
dt_wc <- dt0[Experiment_App=='WeChat']

dt_fb17 <- na.omit(dt_fb, cols = c('activation1', 'activation7'))
m_fb_17 <- lm(activation7~activation1 + Treat , data = dt_fb17)
dt_fb114 <- na.omit(dt_fb, cols = c('activation1', 'activation14'))
m_fb_114 <- dt_fb114[,lm(activation14~activation1 + Treat )]

dt_in17 <- na.omit(dt_in, cols = c('activation1', 'activation7'))
m_in_17 <- lm(activation7~activation1 + Treat , data = dt_in17)
dt_in114 <- na.omit(dt_in, cols = c('activation1', 'activation14'))
m_in_114 <- dt_in114[,lm(activation14~activation1 + Treat )]

dt_wc17 <- na.omit(dt_wc, cols = c('activation1', 'activation7'))
m_wc_17 <- lm(activation7~activation1 + Treat , data = dt_wc17)
dt_wc114 <- na.omit(dt_wc, cols = c('activation1', 'activation14'))
m_wc_114 <- dt_wc114[,lm(activation14~activation1 + Treat )]

dt_fb17 <- na.omit(dt_fb, cols = c('pleasant1', 'pleasant7'))
m_fb_17 <- lm(pleasant7~pleasant1 + Treat , data = dt_fb17)
dt_fb114 <- na.omit(dt_fb, cols = c('pleasant1', 'pleasant14'))
m_fb_114 <- dt_fb114[,lm(pleasant14~pleasant1 + Treat )]

dt_wc17 <- na.omit(dt_wc, cols = c('pleasant1', 'pleasant7'))
m_wc_17 <- lm(pleasant7~pleasant1 + Treat , data = dt_wc17)
dt_wc114 <- na.omit(dt_wc, cols = c('pleasant1', 'pleasant14'))
m_wc_114 <- dt_wc114[,lm(pleasant14~pleasant1 + Treat )]

dt_in17 <- na.omit(dt_in, cols = c('pleasant1', 'pleasant7'))
m_in_17 <- lm(pleasant7~pleasant1 + Treat , data = dt_in17)
dt_in114 <- na.omit(dt_in, cols = c('pleasant1', 'pleasant14'))
m_in_114 <- dt_in114[,lm(pleasant14~pleasant1 + Treat )]
```

```r
# Generic "Activation" Table for both Week-1 and Week-2
stargazer(m_gmood_act7, m_gmood_act14,
          #type="text",
          type="latex",
          se = list(summary(m_gmood_act7)$coefficients[,2],
                    summary(m_gmood_act14)$coefficients[,2]),
          title = "Treatment Effect on \"Activation\" on Week-1 and Week-2",
          header = F,
          font.size = "small",
          dep.var.caption = c("Emotional State \"Activation\" Score"),
          dep.var.labels = c("on Week-1", "on Week-2"),
          covariate.labels = c("\"Activation\" Score Week-0", "Treatment during Week-1"),
          star.cutoffs = c(0.1, 0.05, 0.01)
          )
```

Table 5: Treatment Effect on "Activation" on Week-1 and Week-2

	Emotional State "Activation" Score	
	on Week-1	on Week-2
	(1)	(2)
"Activation" Score Week-0	0.975^{***}	0.629^{***}
	(0.222)	(0.224)
Treatment during Week-1	-2.284	-3.512
	(8.674)	(8.740)
Constant	1.281	34.516^{*}
	(19.921)	(20.074)
Observations	18	18
R^2	0.635	0.437
Adjusted R^2	0.587	0.362
Residual Std. Error (df = 15)	16.157	16.281
F Statistic (df = 2; 15)	13.061^{***}	5.826^{**}
Note:		*p<0.1; **p<0.05; ***p<0.01

```r
# Generic "Pleasant" Table for both Week-1 and Week-2
stargazer(m_gmood_ple7, m_gmood_ple14,
          #type="text",
          type="latex",
          se = list(summary(m_gmood_ple7)$coefficients[,2],
                    summary(m_gmood_ple14)$coefficients[,2]),
          title = "Treatment Effect on \"Activation\" on Week-1 and Week-2",
          header = F,
          font.size = "small",
          dep.var.caption = c("Emotional State \"Pleasant\" Score"),
          dep.var.labels = c("on Week-1", "on Week-2"),
          covariate.labels = c("\"Pleasant\" Score Week-0", "Treatment during Week-1"),
          star.cutoffs = c(0.1, 0.05, 0.01)
          )
```

Table 6: Treatment Effect on "Activation" on Week-1 and Week-2

	Emotional State "Pleasant" Score	
	on Week-1	on Week-2
	(1)	(2)
"Pleasant" Score Week-0	0.895***	0.733***
	(0.173)	(0.194)
Treatment during Week-1	10.695	10.035
	(9.635)	(10.773)
Constant	3.208	28.991
	(18.990)	(21.234)
Observations	18	18
R^2	0.651	0.497
Adjusted R^2	0.605	0.430
Residual Std. Error (df = 15)	18.479	20.663
F Statistic (df = 2; 15)	14.007***	7.419***
Note:	*p<0.1; **p<0.05; ***p<0.01	

```
# App Specific "Activation" Table for both Week-1 and Week-2
stargazer(m_fb_17, m_in_17, m_wc_17, m_fb_114, m_in_114, m_wc_114,
          #type="text",
          type="latex",
          se = list(summary(m_fb_17)$coefficients[,2],
                    summary(m_in_17)$coefficients[,2],
                    summary(m_wc_17)$coefficients[,2]),
          title = "Treatment Effect on \"Activation\" on Week-1 and Week-2",
          header = FALSE,
          font.size = "small",
          float = FALSE,
          float.env = "sidewaystable",
          dep.var.caption = c("Emotional State \"Activation\" Score"),
          dep.var.labels = c("on Week-1", "on Week-2"),
          column.labels = c('Facebook','Instagram','WeChat',
                            'Facebook','Instagram','WeChat'),
          covariate.labels = c("\"Activation\" Score Week-0", "Treatment during Week-1"),
          star.cutoffs = c(0.1, 0.05, 0.01)
          )
```

	Emotional State "Activation" Score					
		on Week-1			on Week-2	
	Facebook	Instagram	WeChat	Facebook	Instagram	WeChat
	(1)	(2)	(3)	(4)	(5)	(6)
"Activation" Score Week-0	0.812***	1.076***	1.235***	0.523	0.306	0.861**
	(0.236)	(0.368)	(0.305)	(0.417)	(0.260)	(0.171)
Treatment during Week-1	6.689	25.407	14.830	21.770	−4.669	−7.493
	(11.949)	(18.568)	(15.995)	(21.595)	(13.942)	(8.228)
Constant	18.570	−31.233	−33.303	32.530	82.842	27.553
	(21.951)	(46.130)	(32.438)	(37.164)	(32.289)	(18.491)
Observations	9	7	7	8	5	6
R^2	0.665	0.699	0.805	0.323	0.741	0.908
Adjusted R^2	0.553	0.548	0.707	0.053	0.481	0.847
Residual Std. Error	17.412 (df = 6)	16.290 (df = 4)	19.998 (df = 4)	29.457 (df = 5)	9.303 (df = 2)	9.261 (df = 3)
F Statistic	5.950** (df = 2; 6)	4.639* (df = 2; 4)	8.253** (df = 2; 4)	1.194 (df = 2; 5)	2.855 (df = 2; 2)	14.874** (df = 2; 3)
Note:						*p<0.1; **p<0.05; ***p<0.01

```
# App Specific "Pleasant" Table for both Week-1 and Week-2
stargazer(m_fb_17, m_in_17, m_wc_17, m_fb_114, m_in_114, m_wc_114,
          #type="text",
          type="latex",
          se = list(summary(m_fb_17)$coefficients[,2],
                    summary(m_in_17)$coefficients[,2],
                    summary(m_wc_17)$coefficients[,2],
                    summary(m_fb_114)$coefficients[,2],
                    summary(m_wc_114)$coefficients[,2],
                    summary(m_in_114)$coefficients[,2]),
          title = "Treatment Effect on \"Pleasant\" on Week-1 and Week-2",
          header = FALSE,
          font.size = "small",
          float = FALSE,
          float.env = "sidewaystable",
          dep.var.caption = c("Emotional State \"Pleasant\" Score"),
          dep.var.labels = c("on Week-1", "on Week-2"),
          column.labels = c('Facebook','Instagram','WeChat',
                          'Facebook','Instagram','WeChat'),
        covariate.labels = c("\"Pleasant\" Score Week-0", "Treatment during Week-1"),
        star.cutoffs = c(0.1, 0.05, 0.01)
        )
```

	Emotional State "Pleasant" Score					
		on Week-1			on Week-2	
	Facebook	Instagram	WeChat	Facebook	Instagram	WeChat
	(1)	(2)	(3)	(4)	(5)	(6)
"Pleasant" Score Week-0	0.812***	1.076***	1.235***	0.523	0.306*	0.861***
	(0.236)	(0.368)	(0.305)	(0.417)	(0.171)	(0.260)
Treatment during Week-1	6.689	25.407	14.830	21.770	−4.669	−7.493
	(11.949)	(18.568)	(15.995)	(21.595)	(8.228)	(13.942)
Constant	18.570	−31.233	−33.303	32.530	82.842***	27.553
	(21.951)	(46.130)	(32.438)	(37.164)	(18.491)	(32.289)
Observations	9	7	7	8	5	6
R^2	0.665	0.699	0.805	0.323	0.741	0.908
Adjusted R^2	0.553	0.548	0.707	0.053	0.481	0.847
Residual Std. Error	17.412 (df = 6)	16.290 (df = 4)	19.998 (df = 4)	29.457 (df = 5)	9.303 (df = 2)	9.261 (df = 3)
F Statistic	5.950** (df = 2; 6)	4.639* (df = 2; 4)	8.253** (df = 2; 4)	1.194 (df = 2; 5)	2.855 (df = 2; 2)	14.874** (df = 2; 3)
Note:						*p<0.1; **p<0.05; ***p<0.01