

241 Project (Summer 2017): Effect of Meditation on Blood Pressure

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Abstract:

We examine the effects of meditation on blood pressure and pulse rates. In particular, using a within-subject experimental design, we compare the effects of a single fifteen-minute meditation session to a similar session of coloring graphic shapes. Subjects were randomly assigned to undergo either the meditation session first, followed by coloring, or the coloring session first, followed by meditation. In each case, a five-minute washout period was inserted between the sessions.

We find that while both meditation and coloring have a significant lowering effect on blood pressure and pulse, the coloring sessions have a greater effect.

Introduction:

Meditation has been used for thousands of years by religious practitioners for spiritual growth. In modern times, it is promoted as a means to reduce stress. Many scientific studies have shown its effectiveness in reducing anxiety and other negative states.

What our the question?

Our study seeks to take this a step further: is it meditation that decreases stress, or is it activities that accompany meditation that are effective? Can other calming activities work as well as meditation to reduce stress? We chose coloring as the activity that most closely resembles traditional meditation without the meditation part. Coloring is a quiet, focused activity, that is not verbal. We chose geometric shapes as a backdrop to avoid the focus on people or cultural associations. Similarly, in meditation there is a distancing of the connection to thoughts and people, and a focus on the abstract. By comparing similar activities, we can narrow our search to those activities that best reduce stress.

Why does it matter?

High blood pressure, left untreated, can harm a person's health for years before symptoms develop. Patients with high blood pressure may become disabled or suffer a fatal heart attack. About half of the people with high blood pressure who are left untreated die of heart disease, and another third die of stroke.

Systolic vs Diastolic Blood Pressure vs Pulse

Our study uses portable wrist blood pressure monitors to measure three numbers: systolic and diastolic blood pressure, and pulse rates. Of these numbers the most important are systolic blood pressure (the first number given when reporting blood pressure), and pulse. Diastolic pressure is generally only used during an emergency such as a cardiac arrest. Pulse is more variable than systolic pressure, but both are indicators of stress levels.

Experiment

Overview

Our experiment observed thirty-two people both in groups and individually, in person and online. Subjects varied in age from under ten years to over eighty, and in years of meditation experience from zero to fifty. These volunteers were primarily drawn from researcher friends and family networks.

Our subjects were randomly divided into two groups: one group that listened to a fifteen-minute guided meditation (from <https://www.appropriateresponse.com/teachings/>) first and spent fifteen minutes coloring after, and another group that engaged in the coloring exercise first, followed by the guided meditation. Between each session, subjects were asked to get up and walk around for 5 minutes, to create a ‘washout’ period and avoid spillover effects.

Subjects were asked to measure their own blood pressure before and after each session, and the results were recorded either by the subject (during group sessions) or by the researcher (for individual sessions) after each measurement.

Considerations

Why within-subject design

The within-subject design gave the study two advantages: first, using the same person to represent both experimental and control conditions gives greater precision around treatment estimates, and second, we were able to use fewer volunteers for the same statistical power.

Within-subject designs have a few potential sources of bias: treatment assignment, anticipation, and persistence. We used an R function to assign subjects to either meditation-first or coloring-first groups. As new volunteers signed up, they were added to the next slot on a list which automatically assigned the pre-randomized group.

To avoid anticipation, subjects were not told what the sessions would entail until the sessions began. There may have been some guesswork, due to our pre-experiment questions that identified years of meditation experience, or to the packages that arrived in the mail that included colored pencils. However, the details were not known to the subjects in advance.

A washout of five minutes was used to combat persistence. While it might have been better to take a longer period of time to ‘reset’ our subjects blood pressures, we tried to keep this time short in consideration of the overall time our volunteers were giving to the study. On average, color-firsters retained a drop of 2.5 points after their initial sessions, while meditate-firsters retained a drop of .9 points.

Why Coloring

Coloring is used quite often in medical experiments as a control activity. We used it because of its similarity to meditation - subjects are focused, seated, not interacting with other people, not required to engage in verbal processing, and silent. It was the closest activity we found that included many of the calming features of meditation, without actually being meditation.

Why a Guided Meditation

We chose an online guided meditation from www.appropriateresponse.com for the meditation sessions. There was a great deal of debate about this choice within the team: meditation styles include silent, guided, mantras, visualizations, music and more. In the end, it was decided that for beginners, a guided meditation would be less arduous. Mantra meditations might be distracting, especially in group settings. In a music meditation, separating out whether it was the music or the meditation that created the effects would be impossible. And visualization meditations might take too long to explain, and have their own set of confounding factors (who gives the instructions, if they would be remembered, etc.).

Guided meditations themselves come with an array of variation. The meditation we chose was deemed to have the least potentially negative reaction, as it avoids spiritual and esoteric language. However, some of the more experienced meditators who were accustomed to a different mediation style reported that they found the guided meditation distracting.

Challenges

BP measurement device precision

While we were pleased to find affordable mobile blood pressure monitors, wrist monitors are not the best measuring devices for precision. Each person required some basic instructions in the use of the monitors - in most cases this was the first time they used a device of this kind, which may have increased the likelihood of measurement error. In one case we were forced to remove the measured results, as they were deemed an error by a medical professional.

Subject inexperience

Experienced meditators often aim for 30 to 60 minutes in a given session. However, this length of time might be uncomfortable for inexperienced meditators, so we limited the sessions to 15 minutes. An interesting follow-up study might test the results of a longer meditation, using only subjects with meditation experience.

Subject participation

The original study design called for subjects to test the long-term results of meditation. For practicality and to avoid non-compliance or attrition, the design was altered to measure the results of a single meditation. A follow up study might take advantage of subjects on a meditation retreat to look for longer term effects, although the generalizability of such findings would certainly be called into question.

Data:

```
library(data.table)
library(sandwich)
library(lmtest)
```

```
FALSE Loading required package: zoo
```

```
FALSE
```

```
FALSE Attaching package: 'zoo'
```

```
FALSE The following objects are masked from 'package:base':
```

```
FALSE
```

```
FALSE      as.Date, as.Date.numeric
```

```
library(stargazer)
```

```
FALSE
```

```
FALSE Please cite as:
```

```
FALSE Hlavac, Marek (2015). stargazer: Well-Formatted Regression and Summary Statistics Tables.
```

```
FALSE R package version 5.2. http://CRAN.R-project.org/package=stargazer
```

```
library(RColorBrewer)
library(cobalt)
library(car)
```

Data Exploration

Read in and clean up the data

```
d <- fread("../data/meditation.csv")
# Should be 32 subjects
cat("Number of rows:", nrow(d), "\n")
```

```
## Number of rows: 32
```

```
str(d)
```

```
## Classes 'data.table' and 'data.frame':  32 obs. of  30 variables:
## $ ID                               : int  1 2 3 4 5 6 7 8 9 10 ...
## $ Group                             : int  0 1 0 1 0 1 0 1 0 0 ...
## $ Recruited_By                       : chr  "Erika" "Erika" "Erika" "Erika" ...
## $ Location                           : chr  "San Diego, CA" "Bellingham, WA" "Lopez Island, WA" "San
## $ Age_Group                           : chr  "40-49" "40-49" "50-59" "50-59" ...
## $ Gender                             : chr  "F" "F" "M" "F" ...
## $ Religion                           : chr  "Buddhist" "Buddhist" "Buddhist" "Spiritual" ...
## $ Pre_existing_blood_pressure         : chr  "Low" "Avg" "Avg" "Low" ...
## $ Years_practice                     : int  25 10 45 47 24 0 0 0 0 2 ...
## $ caffeinated_drinks                  : num  0.5 2 2 1 3 1 1 1 2 2 ...
## $ hours_since_last_caffeinated_drink : num  6 10 6 3 5 1 6 6 0.7 2 ...
## $ Online_in_person                   : chr  "0" "0" "0" "0" ...
## $ Experiment_Date                     : chr  "7/25/2017" "8/2/2017" "7/23/2017" "7/23/2017" ...
## $ Start_Time                          : chr  "3:00 PM" "8:00 PM" "7:45 PM" "1:30 PM" ...
## $ previous_strenuous_activity         : chr  "Yes" "No" "Yes" "Maybe (walking)" ...
## $ Before_Meditation_how_relaxed       : chr  "a little tense" "a little tense" "relaxed" "relaxed" ..
## $ B4_Med_BP_Sys                       : int  112 107 114 134 119 131 108 130 127 114 ...
## $ B4_Med_BP_DIA                       : int  71 59 70 97 81 92 69 88 84 78 ...
## $ B4_Med_BP_PUL                       : int  55 74 78 97 75 76 71 71 90 81 ...
## $ After_Med_BP_Sys                    : int  96 110 122 108 121 125 111 121 106 96 ...
## $ After_Med_BP_DIA                    : int  59 61 73 71 81 88 70 77 77 62 ...
## $ After_Med_BP_PUL                    : int  59 75 85 95 79 76 64 68 89 79 ...
## $ Post_Med_focus                      : num  4 3 4 3 4 3 4 4 3 ...
## $ B4_color_BP_Sys                     : int  108 122 123 121 124 128 111 131 126 116 ...
## $ B4_color_BP_DIA                     : int  64 64 64 91 79 89 70 93 87 81 ...
## $ B4_color_BP_Pul                     : int  54 79 79 100 77 79 63 74 91 85 ...
## $ After_color_BP_Sys                  : int  94 101 109 113 116 130 110 128 128 111 ...
## $ After_color_BP_DIA                  : int  64 57 69 75 65 92 72 87 82 75 ...
## $ After_color_BP_Pul                  : int  59 75 83 93 82 72 68 74 88 77 ...
## $ Enjoy_Coloring                      : num  2 3.5 4 5 4 2 4 4 4 4 ...
## - attr(*, ".internal.selfref")=<externalptr>
```

```
#d[13]
```

```
d <- data.table(d)
```

```
# *****Clean up the data*****
```

```
# 1. We are remove ID = 13 because this person's BP number is likely machine error
```

```
# 2. Reverse group number: 1 should be meditation first aka "med-first",
```

```
# 0 is coloring 1st aka "color-first"
```

```
# 3. convert string categories to numeric
```

```
d2 <- d[ID != 13 , .(Group = ifelse(Group == 0, 1, 0), # Exclude 13th person
  Recruited_By,
```

```

caffeinated_drinks,
Age_Group,
Gender,
Religion,
Years_practice,
hours_since_last_caffeinated_drink,
previous_strenuous_activity,
Before_Meditation_how_relaxed,
Post_Med_focus,
Enjoy_Coloring,
in_person = ifelse(Online_in_person == 'I', 1, 0),
pre_existing_BP = Pre_existing_blood_pressure,
B4_Med_BP_Sys, B4_Med_BP_PUL,
After_Med_BP_Sys, After_Med_BP_PUL,
B4_color_BP_Sys, B4_color_BP_Pul,
After_color_BP_Sys, After_color_BP_Pul) ]

```

```
summary(d2)
```

```

##      Group      Recruited_By      caffeinated_drinks      Age_Group
## Min.   :0.0000      Length:31      Min.   :0.000      Length:31
## 1st Qu.:0.0000      Class :character      1st Qu.:0.250      Class :character
## Median :1.0000      Mode  :character      Median :1.000      Mode  :character
## Mean   :0.5484
## 3rd Qu.:1.0000
## Max.   :1.0000
##      Gender      Religion      Years_practice
## Length:31      Length:31      Min.   : 0.000
## Class :character      Class :character      1st Qu.: 0.000
## Mode  :character      Mode  :character      Median : 0.000
##
##      Mean   : 9.645
##      3rd Qu.:20.500
##      Max.   :47.000
## hours_since_last_caffeinated_drink previous_strenuous_activity
## Min.   : 0.700      Length:31
## 1st Qu.: 2.500      Class :character
## Median : 6.000      Mode  :character
## Mean   : 9.587
## 3rd Qu.:17.500
## Max.   :24.000
## Before_Meditation_how_relaxed Post_Med_focus      Enjoy_Coloring
## Length:31      Min.   :2.000      Min.   :2.000
## Class :character      1st Qu.:3.000      1st Qu.:3.000
## Mode  :character      Median :3.000      Median :4.000
##
##      Mean   :3.339      Mean   :3.645
##      3rd Qu.:4.000      3rd Qu.:4.000
##      Max.   :5.000      Max.   :5.000
##      in_person      pre_existing_BP      B4_Med_BP_Sys      B4_Med_BP_PUL
## Min.   :0.0000      Length:31      Min.   : 92.0      Min.   :55.00
## 1st Qu.:0.0000      Class :character      1st Qu.:108.5      1st Qu.:68.00
## Median :1.0000      Mode  :character      Median :117.0      Median :72.00
## Mean   :0.5806
##      Mean   :117.1      Mean   :73.58
## 3rd Qu.:1.0000      3rd Qu.:126.5      3rd Qu.:78.00
## Max.   :1.0000      Max.   :138.0      Max.   :97.00

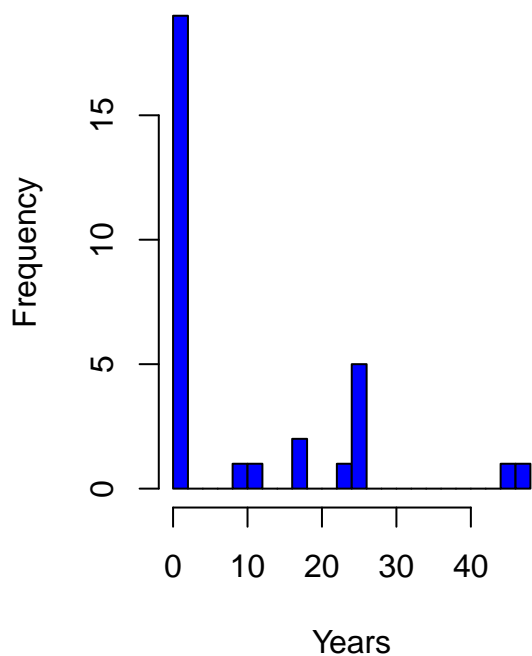
```

```
## After_Med_BP_Sys After_Med_BP_PUL B4_color_BP_Sys B4_color_BP_Pul
## Min. : 85.0 Min. :57.0 Min. : 92.0 Min. : 54.0
## 1st Qu.:103.5 1st Qu.:65.0 1st Qu.:111.0 1st Qu.: 66.5
## Median :111.0 Median :76.0 Median :118.0 Median : 73.0
## Mean :112.1 Mean :74.1 Mean :117.7 Mean : 73.9
## 3rd Qu.:121.0 3rd Qu.:81.0 3rd Qu.:125.5 3rd Qu.: 79.0
## Max. :134.0 Max. :95.0 Max. :140.0 Max. :100.0
## After_color_BP_Sys After_color_BP_Pul
## Min. : 85.0 Min. :53.00
## 1st Qu.:101.0 1st Qu.:68.00
## Median :113.0 Median :74.00
## Mean :110.6 Mean :72.55
## 3rd Qu.:118.0 3rd Qu.:77.00
## Max. :131.0 Max. :93.00
```

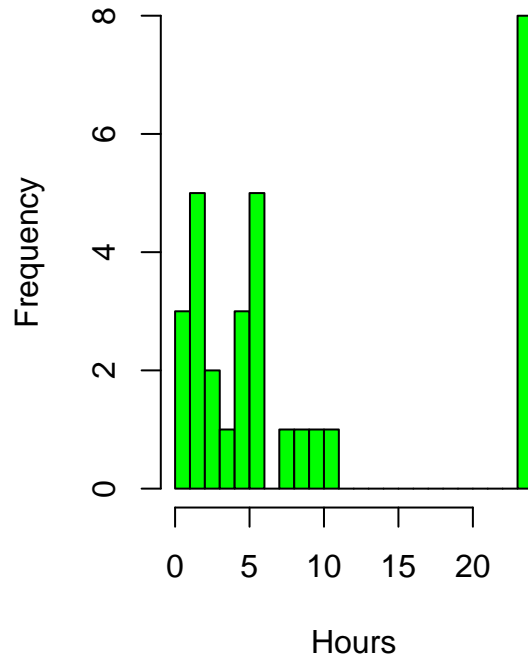
Chart the data

```
par(mfrow=c(1,2))
hist(d2$Years_practice, breaks = 30,col="blue",
     main = "Histogram: Years of Practice", xlab = "Years")
hist(d2$hours_since_last_caffeinated_drink, breaks = 30, col="green",
     main = "Histogram: Hours since Caffeine", xlab = "Hours")
```

Histogram: Years of Practice

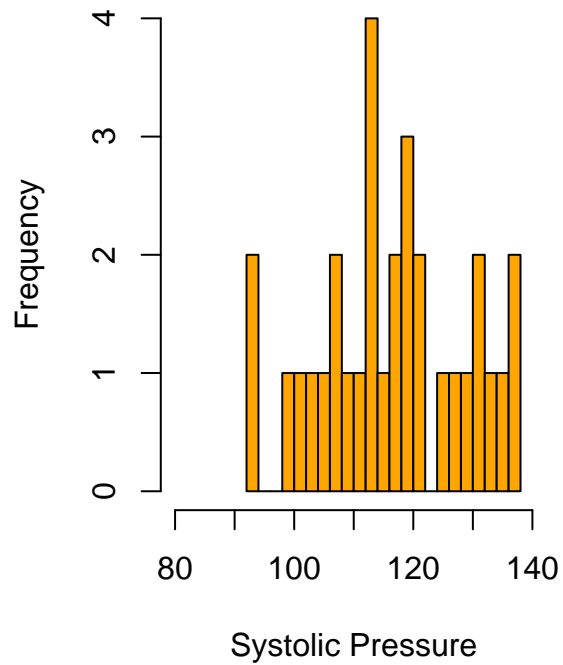


Histogram: Hours since Caffeine

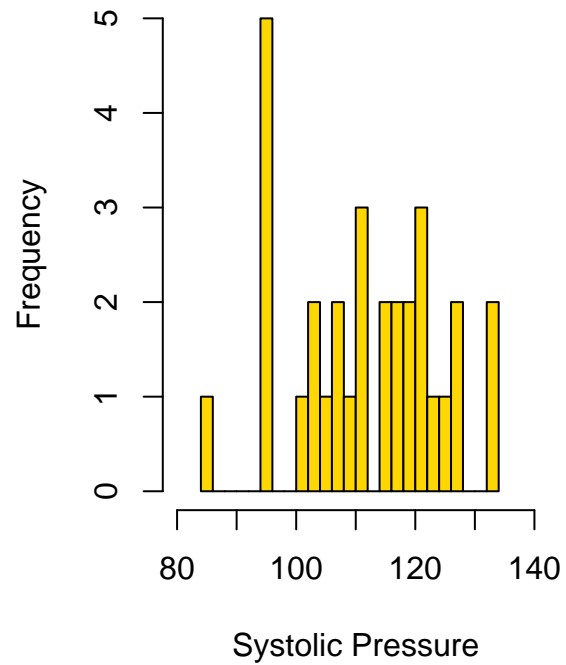


```
hist(d2$B4_Med_BP_Sys, breaks = 30, xlim=c(80,140), col="orange",
     main = "Histogram: Prior Syst.", xlab = "Systolic Pressure")
hist(d2$After_Med_BP_Sys, breaks = 30, xlim=c(80,140),col="gold",
     main = "Histogram: After Meditation Syst.", xlab = "Systolic Pressure")
```

Histogram: Prior Syst.

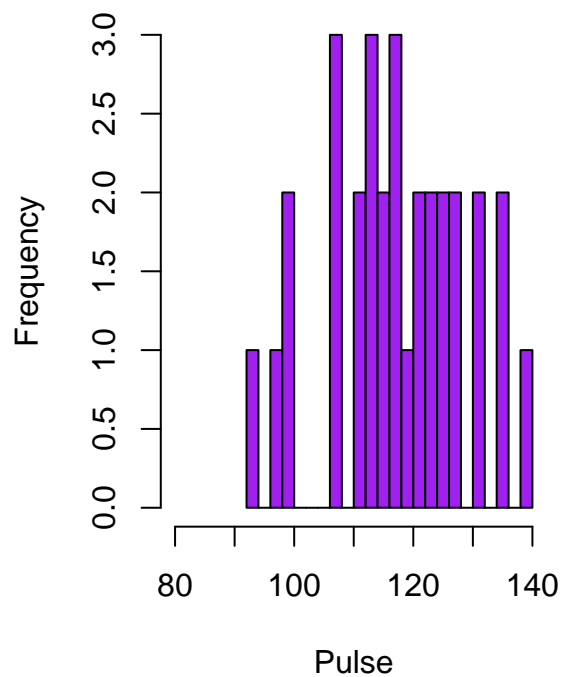


Histogram: After Meditation Sys

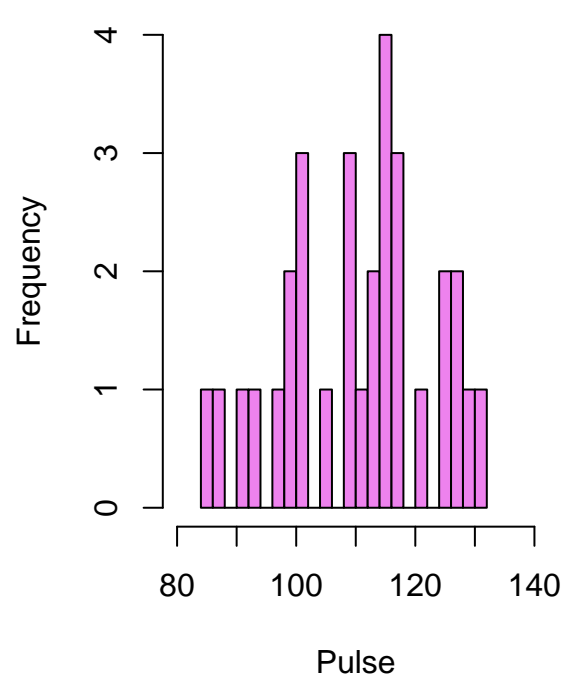


```
hist(d2$B4_color_BP_Sys, breaks = 30, xlim=c(80,140), col="purple",
     main = "Histogram: Prior Pulse", xlab = "Pulse")
hist(d2$After_color_BP_Sys, breaks = 30, xlim=c(80,140), col="violet",
     main = "Histogram: After Meditation Pulse", xlab = "Pulse")
```

Histogram: Prior Pulse



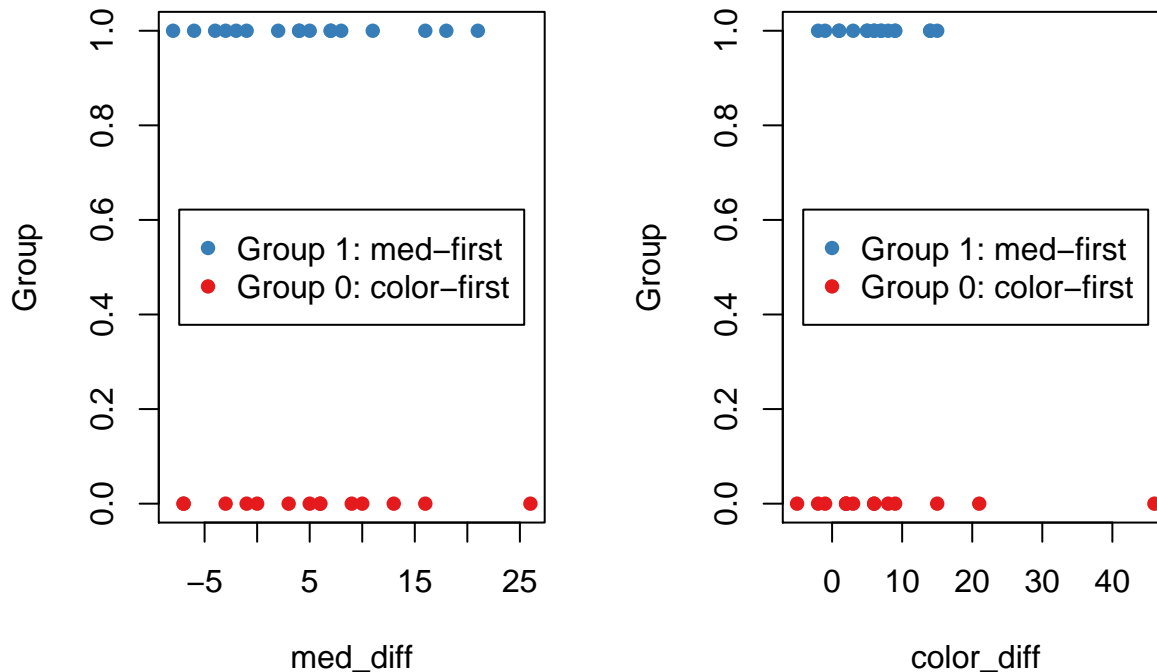
Histogram: After Meditation Puls



```

#display.brewer.all()
cols<-brewer.pal(n=3,name="Set1")
# Note: Group 0 is treatment group!
cols_t1<-cols[d2$Group+1]
med_diff <- d2$B4_Med_BP_Sys - d2$After_Med_BP_Sys
color_diff <- d2$B4_color_BP_Sys - d2$After_color_BP_Sys
par(mfrow =c(1,2))
plot(d2$Group ~ med_diff , col=cols_t1, pch=16, ylab="Group")
legend("center",legend=c("Group 1: med-first", "Group 0: color-first"),
      col=cols_t1, pch=16)
plot(d2$Group ~ color_diff , col=cols_t1, pch=16, ylab="Group")
legend("center",legend=c("Group 1: med-first", "Group 0: color-first"),
      col=cols_t1, pch=16)

```

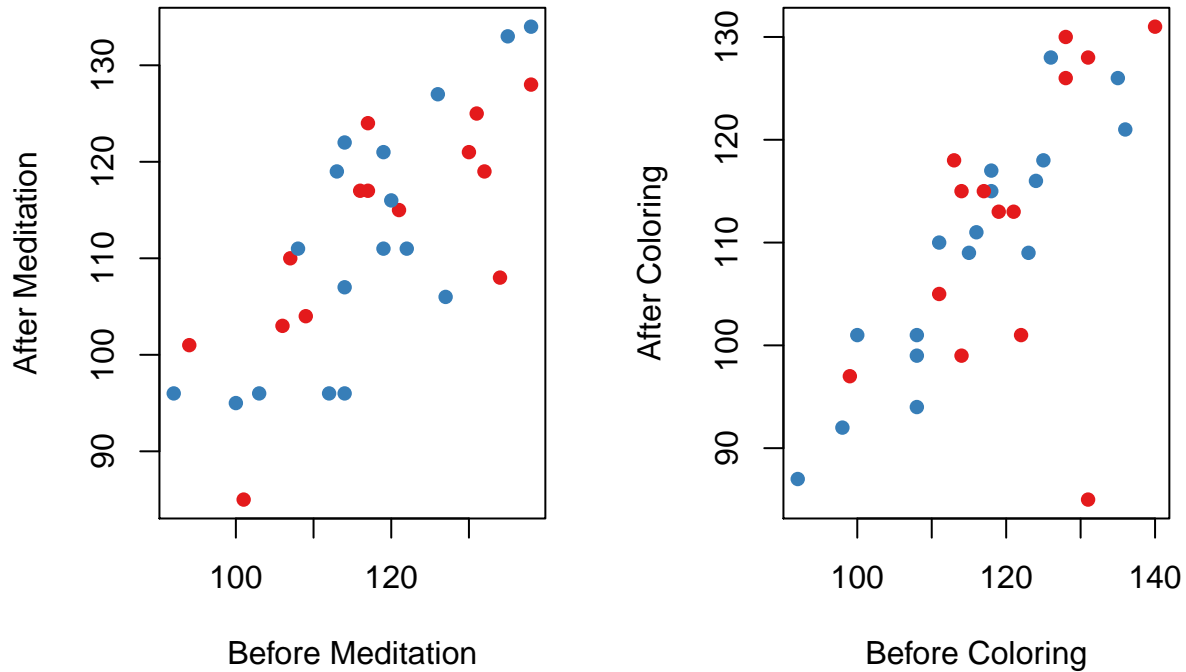


```

# Plot b4 vs after meditation for 2 groups
plot(After_Med_BP_Sys ~ B4_Med_BP_Sys, data=d2 , col=cols_t1, pch=16,
      xlab = "Before Meditation", ylab="After Meditation")
legend(x=98,y=200, legend=c("Group 1: med-first", "Group 0: color-first"),
      col=cols_t1, pch=16, xpd=TRUE)

# Plot b4 vs after coloring for 2 groups
plot(After_color_BP_Sys ~ B4_color_BP_Sys, data=d2 , col=cols_t1, pch=16,
      xlab = "Before Coloring", ylab="After Coloring")
legend(x=100,y=175, legend=c("Group 1: med-first", "Group 0: color-first"),
      col=cols_t1, pch=16, xpd=TRUE)

```

Covariate Balance Check

Matching was performed using the Matching package (Sekhon, 2011), and covariate balance was assessed using cobalt (Greifer, 2017), both in R 3.3.0 (R Core Team, 2016).

When using `bal.tab()` with continuous treatments, the balance statistic presented is the (weighted) Pearson correlation between each covariate and treatment.

```
#data(d2, package = "cobalt")
covs <- subset(d2, select =
  ~c(Group, After_Med_BP_Sys, After_Med_BP_PUL,
      After_color_BP_Sys, After_color_BP_Pul))
#f.build("group", d2)

# Generating ATT weights as specified in Austin (2011)
d2$p.score <- glm(f.build("Group", covs), data = d2,
  family = "binomial")$fitted.values
d2$att.weights <- with(d2, Group + (1-Group)*p.score/(1-p.score))

#bal.tab(covs, treat = d2$Group)
bal.tab(covs, treat = d2$Group, weights = d2$att.weights,
  method = "weighting", estimand="ATE")
```

```
## Balance Measures:
##
## Recruited_By_Erika      Binary -0.0894
## Recruited_By_Post       Binary  0.0408
## Recruited_By_Thong      Binary  0.0486
## caffeinated_drinks      Contin.  0.5225
## Age_Group_10.19         Binary  0.0621
## Age_Group_30.39         Binary -0.0404
## Age_Group_40.49         Binary -0.2363
```

```

## Age_Group_5.9                Binary    0.0007
## Age_Group_50.59              Binary    0.0374
## Age_Group_60.69              Binary    0.0588
## Age_Group_80.90              Binary    0.1176
## Gender_F                     Binary    0.0251
## Religion_Agnostic            Binary    0.0588
## Religion_Buddhist            Binary    0.3146
## Religion_Christian           Binary    0.0304
## Religion_Hindu               Binary    0.1176
## Religion_None                Binary   -0.4523
## Religion_Spiritual           Binary   -0.0692
## Years_practice               Contin.    0.4966
## hours_since_last_caffeinated_drink Contin.  -0.1621
## previous_strenuous_activity_Maybe..walking. Binary -0.1384
## previous_strenuous_activity_No Binary    0.2071
## previous_strenuous_activity_Yes Binary   -0.0687
## Before_Meditation_how_relaxed_a.little.tense Binary  0.2753
## Post_Med_focus               Contin.    0.2986
## Enjoy_Coloring               Contin.    0.0226
## in_person                    Binary   -0.3518
## pre_existing_BP_Avg          Binary   -0.0969
## pre_existing_BP_High         Binary    0.1073
## pre_existing_BP_Low          Binary   -0.0104
## B4_Med_BP_Sys                Contin.   -0.1699
## B4_Med_BP_PUL                Contin.    0.2833
## B4_color_BP_Sys              Contin.   -0.4661
## B4_color_BP_Pul              Contin.   -0.0714
##
## Effective sample sizes:
##           Control Treated
## Unadjusted    14.00     17
## Adjusted     12.02     17

```

Covariate Balance Concerns

Of the covariates analyzed, the following stand out as unbalanced: caffeinated drinks, religion, and years of practice. The Med-First group is more likely to have participants who drink caffeine, are Buddhist and have more meditation experience, while the Color-First group is more likely to include subjects that do not identify with a particular religion.

The difference in prior blood pressure and pulse measures is perhaps even more concerning. Systolic blood pressure measures before coloring for color-first participants tended to be consistently lower than for those starting out with meditation.

In each case, it will be important to include these variables when running regressions, to account for any possible bias.

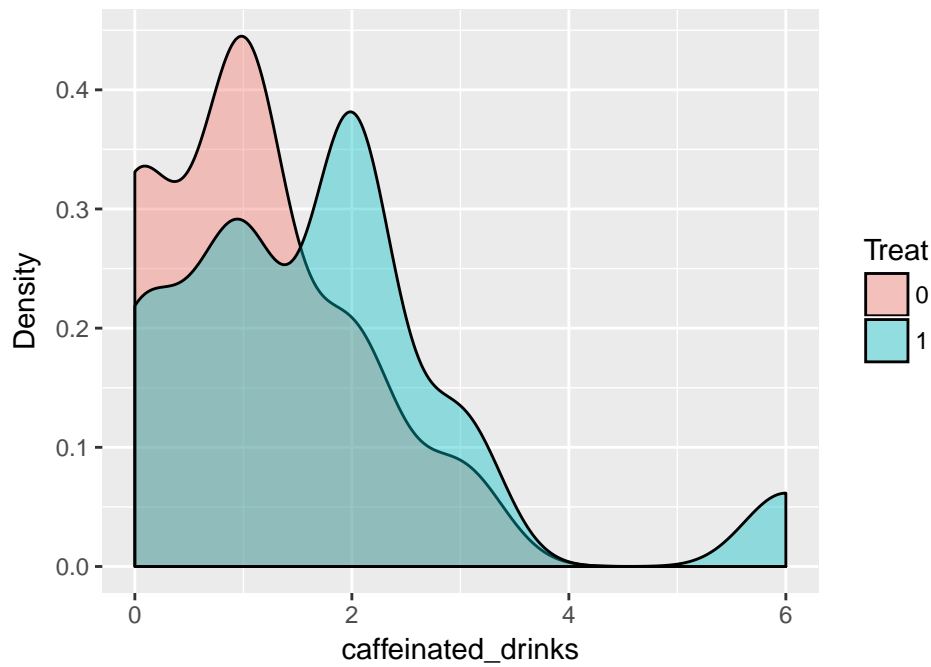
```

bal.plot(covs, treat = d2$Group, weights = d2$att.weights, method = "weighting",
         estimand = "ATT", var.name = "caffeinated_drinks")

```

Distributional Balance for "caffeinated_drinks"

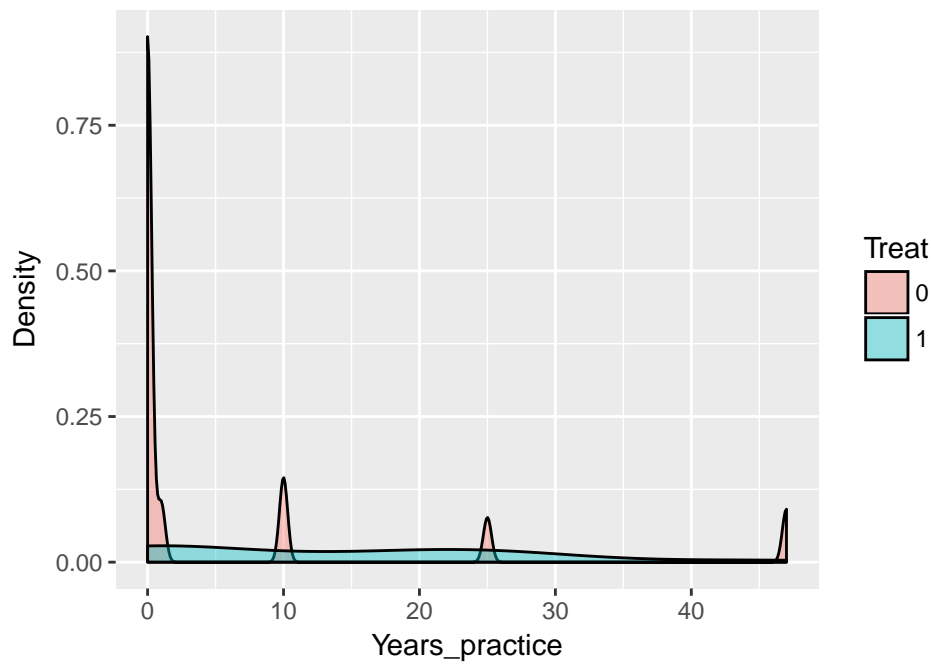
Adjusted Sample



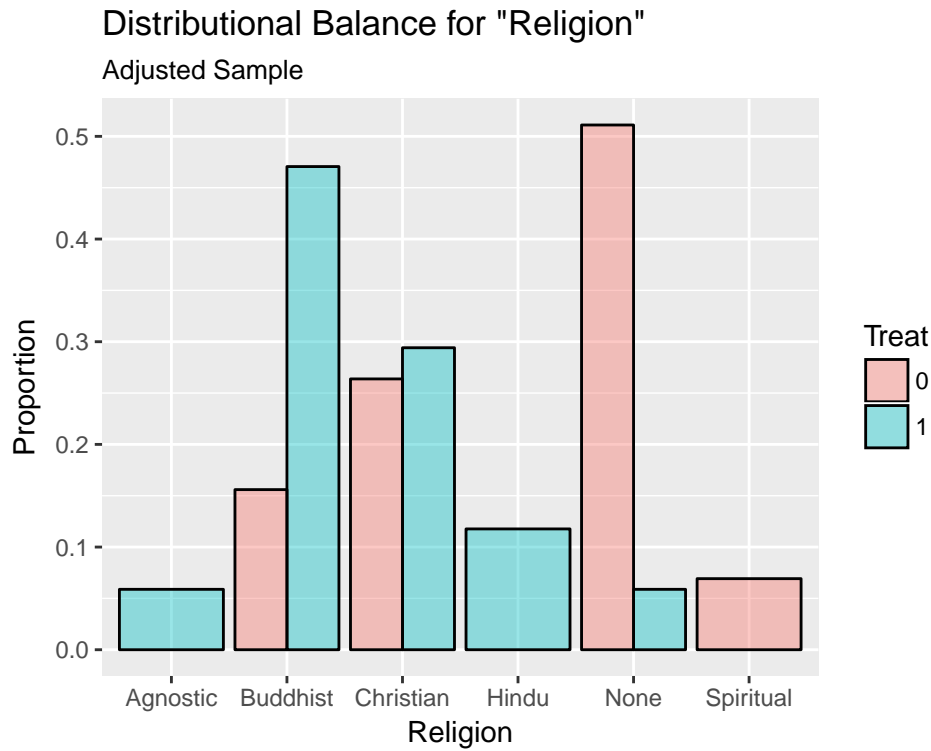
```
bal.plot(covs, treat = d2$Group, weights = d2$att.weights, method = "weighting",  
         estimand = "ATT", var.name = "Years_practice")
```

Distributional Balance for "Years_practice"

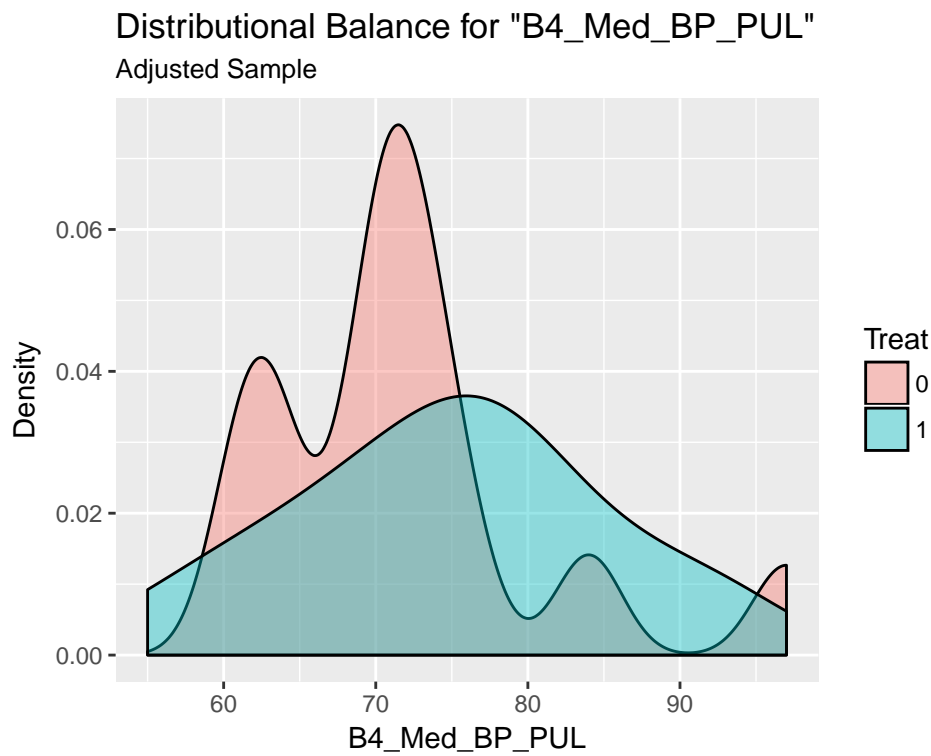
Adjusted Sample



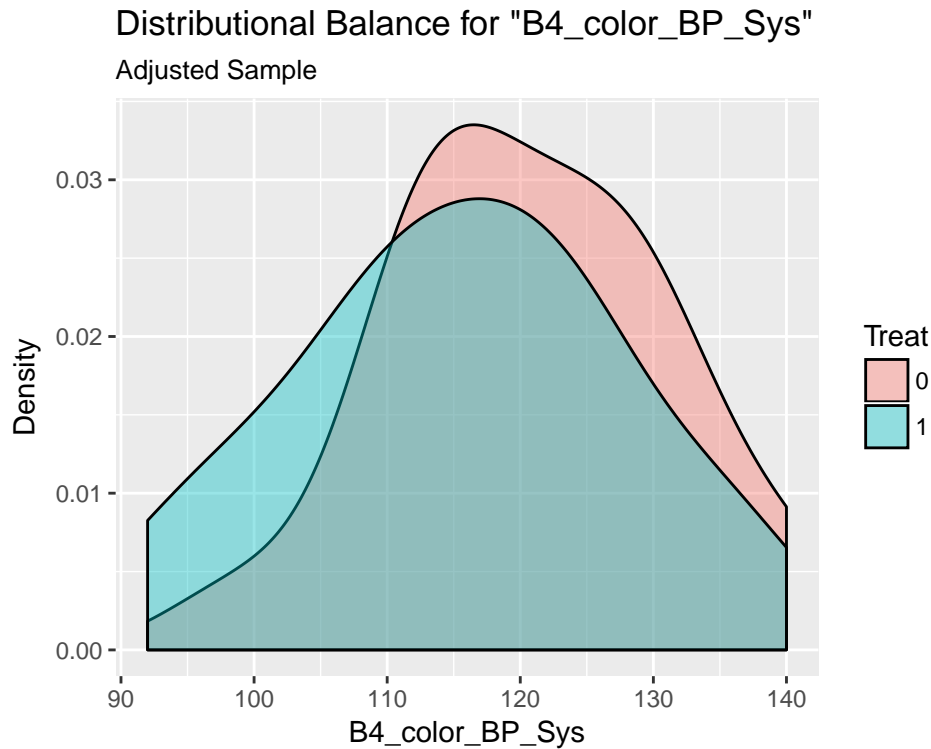
```
bal.plot(covs, treat = d2$Group, weights = d2$att.weights, method = "weighting",  
         estimand = "ATT", var.name = "Religion")
```



```
bal.plot(covs, treat = d2$Group, weights = d2$att.weights, method = "weighting",
         estimand = "ATT", var.name = "B4_Med_BP_PUL")
```



```
bal.plot(covs, treat = d2$Group, weights = d2$att.weights, method = "weighting",
         estimand = "ATT", var.name = "B4_color_BP_Sys")
```



Feature creation and selection

```
#create bins for meditation experience
d2 <- transform(d2, experience=cut(Years_practice,
                                   breaks=c(-1,1, 10, 25, 50),
                                   labels= c(0,10, 25, 50)))
d2 <- transform(d2, exp_bin=cut(Years_practice,
                                breaks=c(-1,0, 50),
                                labels= c(0,1)))
d2 <- transform(d2, pre_med_sys=cut(B4_Med_BP_Sys,
                                    breaks = c(50, 100, 125, 150),
                                    labels = c("low", "med", "high")))
d2 <- transform(d2, pre_col_sys=cut(B4_color_BP_Sys,
                                    breaks = c(50, 100, 125, 150),
                                    labels = c("low", "med", "high")))
d2 <- transform(d2, pre_med_pul=cut(B4_Med_BP_PUL,
                                    breaks = c(50, 70, 90, 110),
                                    labels = c("low", "med", "high")))
d2 <- transform(d2, pre_col_pul=cut(B4_color_BP_Pul,
                                    breaks = c(50, 70, 90, 110),
                                    labels = c("low", "med", "high")))

rel_str = ''
rel_str = "c('Agnostic', 'None', 'Spiritual') = 'NA';"
rel_str = paste(rel_str, " c('Buddhist', 'Hindu') = 'Eastern'; 'Christian' = 'Christian'")
d2$rel <- recode(d2$Religion, rel_str)
age_str = "c('5-9', '10-19') = '< 20'; '30-39' = '30s';"
age_str = paste(age_str, "'40-49' = '40s'; c('50-59', '60-69', '80-90') = '50+'")
d2$age = recode(d2$Age_Group, age_str)
```

```

d2 = transform(d2, latest_fix=cut(hours_since_last_caffeinated_drink,
                                breaks = c(.5, 2, 5, 12, 24),
                                labels = c("<2", "<5", "<12", "24+")))
d2$latest_fix = factor(d2$latest_fix)

d2$prev_act = recode(d2$previous_strenuous_activity, "'No' = 'no'; else='yes'")

#create fields to capture the difference before and after each session
#for clarity, we subtract the number we expect to be smaller (after)
#from the larger (before), to keep the numbers positive
#Systolic
d2$med_sys_diff = d2$B4_Med_BP_Sys - d2$After_Med_BP_Sys
cat("Average Meditation Effect on Systolic Blood Pressure:", mean(d2$med_sys_diff), "\n")

## Average Meditation Effect on Systolic Blood Pressure: 5

d2$col_sys_diff = d2$B4_color_BP_Sys - d2$After_color_BP_Sys
cat("Average Coloring Effect on Systolic Blood Pressure:", mean(d2$col_sys_diff), "\n")

## Average Coloring Effect on Systolic Blood Pressure: 7.064516

#Pulse
d2$med_pul_diff = d2$B4_Med_BP_PUL - d2$After_Med_BP_PUL
cat("Average Meditation Effect on Pulse Rate:", mean(d2$med_pul_diff), "\n")

## Average Meditation Effect on Pulse Rate: -0.516129

d2$col_pul_diff = d2$B4_color_BP_Pul - d2$After_color_BP_Pul
cat("Average Coloring Effect on Pulse Rate:", mean(d2$col_pul_diff), "\n")

## Average Coloring Effect on Pulse Rate: 1.354839

#The Coloring ATE is higher than Meditation, so subtract meditation results from coloring
# Create difference in differences measures between meditation and coloring
cat("\nAverage Difference on Systolic Blood Pressure between Coloring and Meditation Effects:",
    mean(d2$col_sys_diff - d2$med_sys_diff), "\n")

##
## Average Difference on Systolic Blood Pressure between Coloring and Meditation Effects: 2.064516

cat("\nAverage Difference on Pulse Rate between Coloring and Meditation Effects:",
    mean(d2$col_pul_diff - d2$med_pul_diff))

##
## Average Difference on Pulse Rate between Coloring and Meditation Effects: 1.870968

```

Correlations and Complications

```

cat("Are Recruiter, Age and Experience correlated?\n\n")

```

```

## Are Recruiter, Age and Experience correlated?

```

```

cat("Recruiter by Subject Age Group\n")

```

```

## Recruiter by Subject Age Group

```

```

table(d2$Recruited_By, d2$age)

```

```

##

```

```
##           < 20 30s 40s 50+
##   Erika      0   3   4   5
##   Post       5   1   0   1
##   Thong      0   0   8   4

cat("\nExperience by Subject Age Group\n")

##
## Experience by Subject Age Group
table(d2$experience, d2$age)

##
##           < 20 30s 40s 50+
##   0          5   2   7   4
##  10          0   1   1   0
##  25          0   1   4   4
##  50          0   0   0   2

cat("\nATE between meditation vs color by Group. Did we leave enough time for a washout?\n\n")

##
## ATE between meditation vs color by Group. Did we leave enough time for a washout?
ate_group_1_diff = mean(d2$col_sys_diff[d$Group==TRUE], na.rm=TRUE) -
  mean(d2$med_sys_diff[d2$Group==TRUE], na.rm=TRUE)
cat("    Med-first Group Systolic Difference:", round(ate_group_1_diff, 2), "\n")

##    Med-first Group Systolic Difference: 0.35
ate_group_0_diff = mean(d2$col_sys_diff[d$Group==FALSE], na.rm=TRUE) -
  mean(d2$med_sys_diff[d2$Group==FALSE], na.rm=TRUE)
cat("    Color-first Group Systolic Difference:", round(ate_group_0_diff, 2), "\n")

##    Color-first Group Systolic Difference: 3.34
ate_group_1_diff = mean(d2$col_pul_diff[d$Group==TRUE], na.rm=TRUE) -
  mean(d2$med_pul_diff[d2$Group==TRUE], na.rm=TRUE)
cat("    Med-first Group Pulse Difference:", round(ate_group_1_diff, 2), "\n")

##    Med-first Group Pulse Difference: 1.57
ate_group_0_diff = mean(d2$col_pul_diff[d$Group==FALSE], na.rm=TRUE) -
  mean(d2$med_pul_diff[d2$Group==FALSE], na.rm=TRUE)
cat("    Color-first Group Pulse Difference:", round(ate_group_0_diff, 2), "\n")

##    Color-first Group Pulse Difference: 2.97
```

Based on these results, it would be best to include either Age, or Experience or Recruiter in a model because they are correlated. Always include Group, as the washout period may have been less effected that we might have hoped.

Model Building:

Meditation Effects:

```
#Systolic Blood Pressure
med_sys_exp_ols = lm(med_sys_diff ~ Group + pre_med_sys + experience + Gender +
  Religion + caffeinated_drinks + in_person +
```

```

        prev_act + Before_Meditation_how_relaxed + Post_Med_focus , data=d2)

#summary(med_sys_exp_ols)
med_sys_age_ols = lm(med_sys_diff ~ Group + pre_med_sys + age + Gender +
        Religion + caffeinated_drinks + in_person +
        prev_act + Before_Meditation_how_relaxed + Post_Med_focus , data=d2)

#summary(med_sys_age_ols)
#Pulse
med_pul_exp_ols = lm(med_pul_diff ~ Group + pre_med_pul + experience + Gender +
        Religion + caffeinated_drinks + in_person +
        prev_act + Before_Meditation_how_relaxed + Post_Med_focus , data=d2)

#summary(med_pul_exp_ols)
med_pul_age_ols = lm(med_pul_diff ~ Group + pre_med_pul + age + Gender +
        Religion + caffeinated_drinks + in_person +
        prev_act + Before_Meditation_how_relaxed + Post_Med_focus , data=d2)

#summary(med_pul_age_ols)

```

Color Effects:

```

col_sys_exp_ols = lm(col_sys_diff ~ Group + pre_col_sys + experience +
        Religion + caffeinated_drinks + in_person +
        prev_act + Enjoy_Coloring , data=d2)

#summary(col_sys_exp_ols)
col_sys_age_ols = lm(col_sys_diff ~ Group + pre_col_sys + age +
        Religion + caffeinated_drinks + in_person +
        prev_act + Enjoy_Coloring , data=d2)

#summary(col_sys_age_ols)
#Pulse
col_pul_exp_ols = lm(col_pul_diff ~ Group + pre_col_pul + experience +
        Religion + caffeinated_drinks + in_person +
        prev_act + Enjoy_Coloring , data=d2)

#summary(col_pul_exp_ols)
col_pul_age_ols = lm(col_pul_diff ~ Group + pre_col_pul + age +
        Religion + caffeinated_drinks + in_person +
        prev_act + Enjoy_Coloring , data=d2)

#summary(col_pul_age_ols)

```

Compare the Meditation and Color effects linear models, separately

```

#compare meditation models
cat("Meditation Model Comparison\n")

```

```

## Meditation Model Comparison

```



```
stargazer(med_sys_exp_ols, med_sys_age_ols, med_pul_exp_ols, med_pul_age_ols, type = "text")
```

```
##
## =====
##                               Dependent variable:
##                               -----
##                               med_sys_diff    med_pul_diff
##                               (1)          (2)      (3)          (4)
##                               -----
## Group                               9.220**    4.209    7.458*    5.451*
##                               (3.542)    (4.256)    (4.055)    (3.025)
##
## pre_med_sysmed                     13.914*** 12.509*
##                               (4.030) (5.864)
##
## pre_med_syshigh                     16.164*** 16.617**
##                               (4.694) (7.198)
##
## pre_med_pulmed                               0.452    0.677
##                               (2.881)    (2.414)
##
## pre_med_pulhigh                               6.920    13.862*
##                               (7.396)    (7.275)
##
## experience10                          17.682***    -4.670
##                               (5.227)    (5.989)
##
## experience25                          7.002*    -10.625**
##                               (3.744)    (4.081)
##
## experience50                         -11.885    -10.887
##                               (7.009)    (7.879)
##
## age30s                               -5.646    11.677
##                               (10.024)    (6.976)
##
## age40s                               -11.464    16.161**
##                               (8.692)    (5.670)
##
## age50+                               -10.894    17.107***
##                               (8.212)    (5.196)
##
## GenderM                             6.590*    -1.025    -1.722    5.224*
##                               (3.105)    (3.932)    (3.101)    (2.613)
##
## ReligionBuddhist                    -14.865* -15.213    2.887    -7.895
##                               (7.068) (9.435)    (7.879)    (6.167)
##
## ReligionChristian                    -8.015    -16.130    -0.385    -0.690
##                               (6.870) (10.560) (7.817)    (7.708)
##
## ReligionHindu                       -22.504** -12.052    -0.613    -13.808
##                               (8.566) (11.747) (9.995)    (7.849)
##
```

```
## ReligionNone          -4.871    -6.781     2.461    -11.356
##                      (7.983)   (9.825)   (9.258)   (7.053)
##
## ReligionSpiritual      31.781**    8.292    13.748    -3.171
##                      (11.867)   (12.753) (16.148) (11.501)
##
## caffeinated_drinks    -2.040**    -0.640     1.054    -0.859
##                      (0.852)   (1.586)   (0.877)   (1.093)
##
## in_person              6.346*     0.905     0.609     8.236**
##                      (3.295)   (4.678)   (3.985)   (3.530)
##
## prev_actyes            12.190***    5.951    -5.279    -6.324**
##                      (3.101)   (4.173)   (3.596)   (2.914)
##
## Before_Meditation_how_relaxedrelaxed -7.798**    -5.135    -1.857    -4.633
##                      (2.759)   (4.580)   (3.054)   (3.208)
##
## Post_Med_focus         1.125     1.317     1.539     0.143
##                      (1.659)   (2.303)   (1.833)   (1.578)
##
## Constant              -15.785     7.858    -6.316    -14.412
##                      (10.077)   (14.852) (10.182) (10.056)
##
## -----
## Observations           31         31         31         31
## R2                     0.854     0.704     0.671     0.738
## Adjusted R2            0.664     0.318     0.240     0.394
## Residual Std. Error (df = 13) 4.981     7.100     5.493     4.905
## F Statistic (df = 17; 13)    4.490***    1.821     1.559     2.149*
## =====
## Note:                      *p<0.1; **p<0.05; ***p<0.01
```

```
#compare coloring models
cat("\n\nColor Model Comparison\n")
```

```
##
##
## Color Model Comparison

stargazer(col_sys_exp_ols, col_sys_age_ols, col_pul_exp_ols, col_pul_age_ols, type = "text")

##
## =====
##                               Dependent variable:
##                               -----
##                               col_sys_diff    col_pul_diff
##                               (1)      (2)      (3)      (4)
##                               -----
## Group                        -2.376    -4.431     0.819    -3.550
##                               (6.826)    (4.773)   (3.026)   (2.517)
##
## pre_col_sysmed               9.077    14.862**
##                               (6.267)    (6.394)
##
```

## pre_col_syshigh	11.040	19.931**		
##	(6.723)	(7.203)		
##				
## pre_col_pulmed		4.086*	3.369	
##		(1.937)	(1.937)	
##				
## pre_col_pulhigh		29.493***	29.196***	
##		(5.472)	(6.141)	
##				
## experience10	10.783	5.604		
##	(8.953)	(4.275)		
##				
## experience25	3.017	-0.582		
##	(6.131)	(2.875)		
##				
## experience50	3.509	-5.175		
##	(12.589)	(6.149)		
##				
## age30s		-17.041*	-6.407	
##		(9.621)	(4.889)	
##				
## age40s		-17.633*	-9.516*	
##		(9.947)	(4.697)	
##				
## age50+		-22.432**	-6.045	
##		(9.248)	(4.002)	
##				
## ReligionBuddhist	14.454	24.923**	23.582***	19.891**
##	(13.347)	(10.500)	(6.677)	(6.808)
##				
## ReligionChristian	20.872	22.234*	30.074***	22.406**
##	(12.520)	(11.124)	(6.770)	(7.901)
##				
## ReligionHindu	8.304	23.744*	28.014***	30.064***
##	(14.853)	(13.054)	(7.687)	(8.406)
##				
## ReligionNone	11.612	19.707	30.134***	25.974***
##	(15.205)	(11.327)	(7.487)	(7.291)
##				
## ReligionSpiritual	1.896	14.993	9.427	-2.124
##	(21.717)	(15.143)	(9.873)	(7.044)
##				
## caffeinated_drinks	-0.386	2.130	-0.274	0.514
##	(1.504)	(1.690)	(0.663)	(0.829)
##				
## in_person	-2.975	-8.659*	-4.983*	-6.823**
##	(5.572)	(4.633)	(2.613)	(2.424)
##				
## prev_actyes	3.950	4.248	0.021	-1.472
##	(5.175)	(3.939)	(2.647)	(2.100)
##				
## Enjoy_Coloring	3.795	2.573	0.293	-0.383
##	(2.402)	(2.370)	(1.183)	(1.151)
##				

```
## Constant                -29.022   -18.665   -27.957***   -11.154
##                        (18.390) (17.310)   (8.028)   (10.774)
##
## -----
## Observations              31         31         31         31
## R2                       0.523      0.634      0.790      0.808
## Adjusted R2              0.047      0.267      0.580      0.616
## Residual Std. Error (df = 15) 9.057      7.942      4.261      4.073
## F Statistic (df = 15; 15)    1.098      1.729      3.762***   4.213***
## =====
## Note:                      *p<0.1; **p<0.05; ***p<0.01
```

Difference-in-difference Estimate

```
# Create some Diff variables
d2$col_med_sys_diff = d2$col_sys_diff - d2$med_sys_diff
d2$col_med_pul_diff = d2$col_pul_diff - d2$med_pul_diff
d2$pre_sys_diff= d2$B4_color_BP_Sys - d2$B4_Med_BP_Sys
d2$pre_pul_diff= d2$B4_color_BP_Pul - d2$B4_Med_BP_PUL

cat("Difference in differences on systolic blood pressure:", mean(d2$col_med_sys_diff))

## Difference in differences on systolic blood pressure: 2.064516
cat("\nDifference in differences on pulse rate:", mean(d2$col_med_pul_diff), "\n")

##
## Difference in differences on pulse rate: 1.870968
t.test(d2$col_sys_diff, d2$med_sys_diff)

##
## Welch Two Sample t-test
##
## data: d2$col_sys_diff and d2$med_sys_diff
## t = 0.90894, df = 59.653, p-value = 0.367
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -2.479391 6.608423
## sample estimates:
## mean of x mean of y
## 7.064516 5.000000
t.test(d2$col_pul_diff, d2$med_pul_diff)

##
## Welch Two Sample t-test
##
## data: d2$col_pul_diff and d2$med_pul_diff
## t = 1.1437, df = 59.893, p-value = 0.2573
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -1.401441 5.143377
## sample estimates:
## mean of x mean of y
```

```
## 1.354839 -0.516129
```

Linear Regression model with difference-in-difference Estimate

```
cat("\nDifference in Differences Model Comparison:\n")
```

```
##
```

```
## Difference in Differences Model Comparison:
```

```
dd_sys_ols1 = lm(col_med_sys_diff~ Group + pre_sys_diff + experience + Gender +  
  Religion + caffeinated_drinks + in_person +  
  prev_act + Before_Meditation_how_relaxed + Post_Med_focus, data = d2)
```

```
dd_sys_ols2 = lm(col_med_sys_diff~ Group + pre_sys_diff + age + Gender +  
  Religion + caffeinated_drinks + in_person +  
  prev_act + Before_Meditation_how_relaxed + Post_Med_focus, data = d2)
```

```
dd_pul_ols1 = lm(col_med_pul_diff~ Group + pre_pul_diff + experience + Gender +  
  Religion + caffeinated_drinks + in_person +  
  prev_act + Before_Meditation_how_relaxed + Post_Med_focus, data = d2)
```

```
dd_pul_ols2 = lm(col_med_pul_diff~ Group + pre_pul_diff + age + Gender +  
  Religion + caffeinated_drinks + in_person +  
  prev_act + Before_Meditation_how_relaxed + Post_Med_focus, data = d2)
```

```
stargazer(dd_sys_ols1, dd_sys_ols2, dd_pul_ols1, dd_pul_ols2,type = "text")
```

```
##
```

```
## =====
```

```
##                               Dependent variable:
```

```
##                               -----
```

```
##                               col_med_sys_diff  col_med_pul_diff  
##                               (1)             (2)             (3)             (4)
```

```
## -----
```

```
## Group                        -4.789    -0.250    -1.520    -5.793*  
##                               (5.832)    (5.538)    (4.825)    (3.074)
```

```
##                               pre_sys_diff  
##                               0.749*** 0.811***  
##                               (0.208) (0.233)
```

```
##                               pre_pul_diff  
##                               1.127*** 0.670**  
##                               (0.341) (0.248)
```

```
##                               experience10  
##                               -6.144    2.474  
##                               (8.237)    (7.480)
```

```
##                               experience25  
##                               1.375    6.223  
##                               (5.706)    (5.140)
```

```
##                               experience50  
##                               6.946    -6.245  
##                               (10.979)    (9.403)
```

```
##                               age30s  
##                               -1.825    -11.721*  
##                               (10.554)    (6.631)
```

```
##                               age40s  
##                               4.638    -22.452***
```

##		(9.583)		(5.979)
##				
## age50+		1.110		-19.624***
##		(9.291)		(5.388)
##				
## GenderM	-0.091	0.646	3.383	-4.519
##	(4.338)	(4.076)	(3.778)	(2.678)
##				
## ReligionBuddhist	30.568**	36.427***	7.245	5.033
##	(10.575)	(9.188)	(9.403)	(5.846)
##				
## ReligionChristian	28.789**	35.840***	10.845	-0.518
##	(10.401)	(11.197)	(9.143)	(7.251)
##				
## ReligionHindu	28.050*	28.575**	14.611	18.465**
##	(13.162)	(12.101)	(11.678)	(7.462)
##				
## ReligionNone	21.715	29.114**	11.044	12.946*
##	(12.581)	(10.330)	(10.774)	(6.406)
##				
## ReligionSpiritual	1.180	18.299	6.651	-11.429
##	(19.132)	(14.344)	(15.900)	(8.898)
##				
## caffeinated_drinks	0.882	0.935	-0.507	1.096
##	(1.225)	(1.738)	(1.077)	(1.062)
##				
## in_person	-7.021	-5.433	-7.917*	-15.484***
##	(4.987)	(5.167)	(4.333)	(3.230)
##				
## prev_actyes	-1.662	1.921	7.196*	4.545
##	(4.523)	(4.721)	(3.963)	(2.796)
##				
## Before_Meditation_how_relaxedrelaxed	4.228	2.501	3.457	6.764**
##	(4.276)	(5.258)	(3.721)	(3.083)
##				
## Post_Med_focus	-1.860	-1.285	-1.696	-1.044
##	(2.403)	(2.501)	(2.104)	(1.508)
##				
## Constant	-14.262	-28.374*	-3.847	24.769**
##	(14.317)	(15.603)	(13.085)	(11.213)
##				
##	-----	-----	-----	-----
## Observations	31	31	31	31
## R2	0.802	0.809	0.759	0.878
## Adjusted R2	0.576	0.590	0.483	0.739
## Residual Std. Error (df = 14)	7.723	7.597	6.717	4.776
## F Statistic (df = 16; 14)	3.552**	3.699***	2.751**	6.296***
##	=====	=====	=====	=====
## Note:		*p<0.1; **p<0.05; ***p<0.01		

Results:

- Both coloring and meditation have a lowering effect on blood pressure and pulse. Our results show the effect from coloring being more powerful than meditation. However, t-tests show that this difference is not statistically significant. A number of variables influence the variation in our results:

Meditation

- A number of variables were found to influence the results of meditation on systolic blood pressure and pulse. In both cases, the **Group** was significant, telling us that the washout period was not sufficient to avoid spillover effects. One of the most significant variables influencing systolic blood pressure differences was the **initial systolic blood pressure**: those subjects who began the session with a higher systolic measure were most likely to have a larger difference. **Initial pulse** was significant to a lesser degree on the post-meditation pulse measurement. **Experience** also played a key role, particularly for participants who had 1 to 10 years of meditation experience. While those with 10 to 25 years of experience were most likely to see a benefit on meditation to their pulse rates. **Previous activity** was also highly significant in a greater difference for systolic blood pressure from meditation, and on pulse to a lesser degree. While **Religion** had little effect on pulse, those who identified with a particular faith showed a lessening effect for meditation on blood pressure. **Caffeinated beverages** were significant for blood pressure only. And pulse dropped more when the experiment was conducted **in person**, less so for blood pressure.

To the researchers, the biggest surprise in these results was that those who espoused a particular religion, particularly those that are associated with meditation (Buddhism and Hinduism), saw the smallest effect of the meditation session on blood pressure. It may be that for people who are more accustomed to meditation, the particular format of the guided meditation was distracting, or that a longer meditation would have revealed different results. It is also possible that over time, meditation has less of an effect on a person's blood pressure. This would be a very interesting subject for a future study.

Coloring:

In contrast, those who identified with a particular **Religion** saw significant positive impact on coloring effects on pulse rates, and to a lesser degree on systolic blood pressure. In this case, those who identified as having no **religion** also saw a positive benefit, while those identifying as agnostic or 'other' did not have a significant effect. As expected, **prior measurements** of blood pressure and pulse were highly significant. **Age** was significant as well: people over 40 were also much more likely to find coloring highly beneficial. In contrast to meditation, **in person** sessions were less beneficial for colorers - possibly because in person sessions were sometimes conducted with groups, and social anxiety around artistic talents could have taken away from the overall calming effects of coloring.

Summary

Conclusions

Generalization

Can't generalize from this finding because:

Subjects are our friends and relatives. This sample is not randomized from the general population therefore doesn't represent the population's distribution

Future Research