A/B Testing Example

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```
setwd("~/GB 740")
rocketdata <- read.csv("rocketfuel_deciles.csv")
summary(rocketdata)
```

```
##     user_id             test        converted          tot_impr
##  Min.   : 900000   Min.   :0.00   Min.   :0.00000   Min.   :   1.00
##  1st Qu.:1143190   1st Qu.:1.00   1st Qu.:0.00000   1st Qu.:   4.00
##  Median :1313725   Median :1.00   Median :0.00000   Median :  13.00
##  Mean   :1310692   Mean   :0.96   Mean   :0.02524   Mean   :  24.82
##  3rd Qu.:1484088   3rd Qu.:1.00   3rd Qu.:0.00000   3rd Qu.:  27.00
##  Max.   :1654483   Max.   :1.00   Max.   :1.00000   Max.   :2065.00
##  mode_impr_day   mode_impr_hour  tot_impr_decile
##  Min.   :1.000   Min.   : 0.00   Min.   : 1.00
##  1st Qu.:2.000   1st Qu.:11.00   1st Qu.: 3.00
##  Median :4.000   Median :14.00   Median : 5.00
##  Mean   :4.026   Mean   :14.47   Mean   : 5.38
##  3rd Qu.:6.000   3rd Qu.:18.00   3rd Qu.: 8.00
##  Max.   :7.000   Max.   :23.00   Max.   :10.00
```

```
library(psych)
psych::describe(rocketdata)
```

```
##                 vars      n       mean        sd  median    trimmed       mad
## user_id            1 588101 1310692.22 202225.98 1313725 1313693.47 252713.62
## test               2 588101       0.96      0.20       1       1.00      0.00
## converted          3 588101       0.03      0.16       0       0.00      0.00
## tot_impr           4 588101      24.82     43.72      13      16.27     14.83
## mode_impr_day      5 588101       4.03      2.00       4       4.03      2.97
## mode_impr_hour     6 588101      14.47      4.83      14      14.59      4.45
## tot_impr_decile    7 588101       5.38      2.95       5       5.35      2.97
##                   min     max  range  skew kurtosis     se
## user_id         9e+05 1654483 754483 -0.10    -1.04 263.70
## test            0e+00       1      1 -4.69    20.04   0.00
## converted       0e+00       1      1  6.05    34.65   0.00
## tot_impr        1e+00    2065   2064  7.43   109.92   0.06
## mode_impr_day   1e+00       7      6 -0.04    -1.24   0.00
## mode_impr_hour  0e+00      23     23 -0.34     0.10   0.01
## tot_impr_decile 1e+00      10      9 -0.03    -1.21   0.00
```

```
#The mean of 0.96 for test lines up with the case study reading. This indicates that the control group
#It looks like around 3% of individuals exposed to the advertisement actually purchased the hand bag
#The average number of impressions an individual encountered was around 25 but we can see that there is
#On average Thursday was the day where users encountered the most impressions, but this could be becaus
```

```r
library(knitr)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(ggplot2)
```

```
##
## Attaching package: 'ggplot2'

## The following objects are masked from 'package:psych':
##
##     %+%, alpha
```

```r
attach(rocketdata)
rocket_treatment <- matrix(NA, nrow = 2, ncol = 2)
rocket_treatment[1,] <- format(table(test), digits=1)
rocket_treatment[2,] <- format(prop.table(table(test)), digits = 3)
rownames(rocket_treatment) <- c("Frequency", "Proportion")
colnames(rocket_treatment) <- c("Control", "Treatment")
kable(rocket_treatment)
```

	Control	Treatment
Frequency	23524	564577
Proportion	0.04	0.96

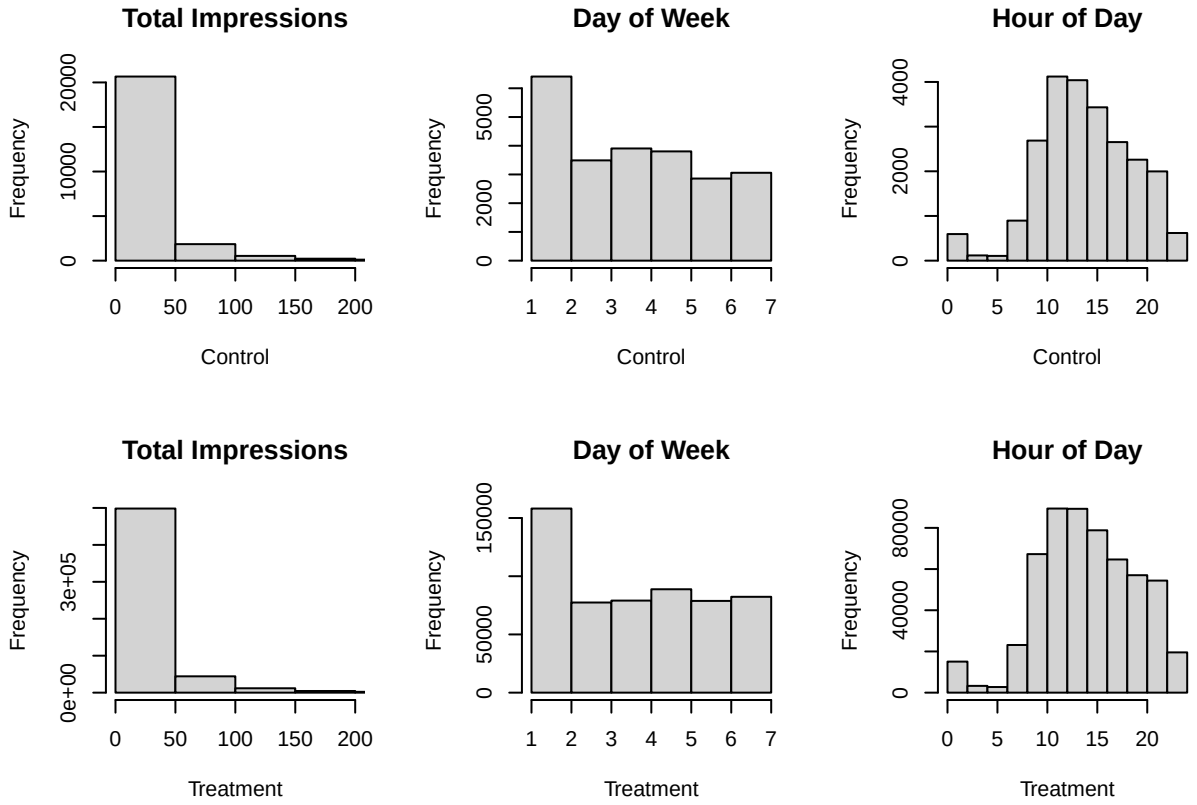
```r
#Our table above aligns with what we read in the case report as our control group represents 4% of the
detach(rocketdata)
```

```r
attach(rocketdata)
balance_check <- rocketdata %>%
     select(tot_impr, mode_impr_day, mode_impr_hour)
balance_table <- matrix(NA, nrow = 3, ncol = 2)
colnames(balance_table) <- c("Mean Control", "Mean Treatment")
rownames(balance_table) <- colnames(balance_check)
m <- as.matrix(round(aggregate(.~test, balance_check, mean),2))
balance_table[,1:2] <- t(m)[2:4,]
kable(balance_table)
```

	Mean Control	Mean Treatment
tot_impr	24.76	24.82
mode_impr_day	3.95	4.03
mode_impr_hour	14.30	14.48

```
#The means of variables across both the treatment and control group look pretty similar. This means if
#Lets show this graphically with histograms
detach(rocketdata)
```

```
attach(rocketdata)
par(mfrow=c(2,3))
hist(tot_impr[test==0], main = paste("Total Impressions"), xlab = "Control", xlim=c(0,200))
hist(mode_impr_day[test==0], main = paste("Day of Week"), xlab = "Control", breaks = 6)
hist(mode_impr_hour[test==0], main = paste("Hour of Day"), xlab = "Control")
hist(tot_impr[test==1], main = paste("Total Impressions"), xlab = "Treatment", xlim=c(0,200), breaks = 4
hist(mode_impr_day[test==1], main = paste("Day of Week"), xlab = "Treatment", breaks = 6)
hist(mode_impr_hour[test==1], main = paste("Hour of Day"), xlab = "Treatment", breaks=13)
```




```
#The histograms also show that our data looks similar across treatment and control groups
detach(rocketdata)
```

```
attach(rocketdata)
#Now it is time to see the means and CIs across the control and treatment group
```

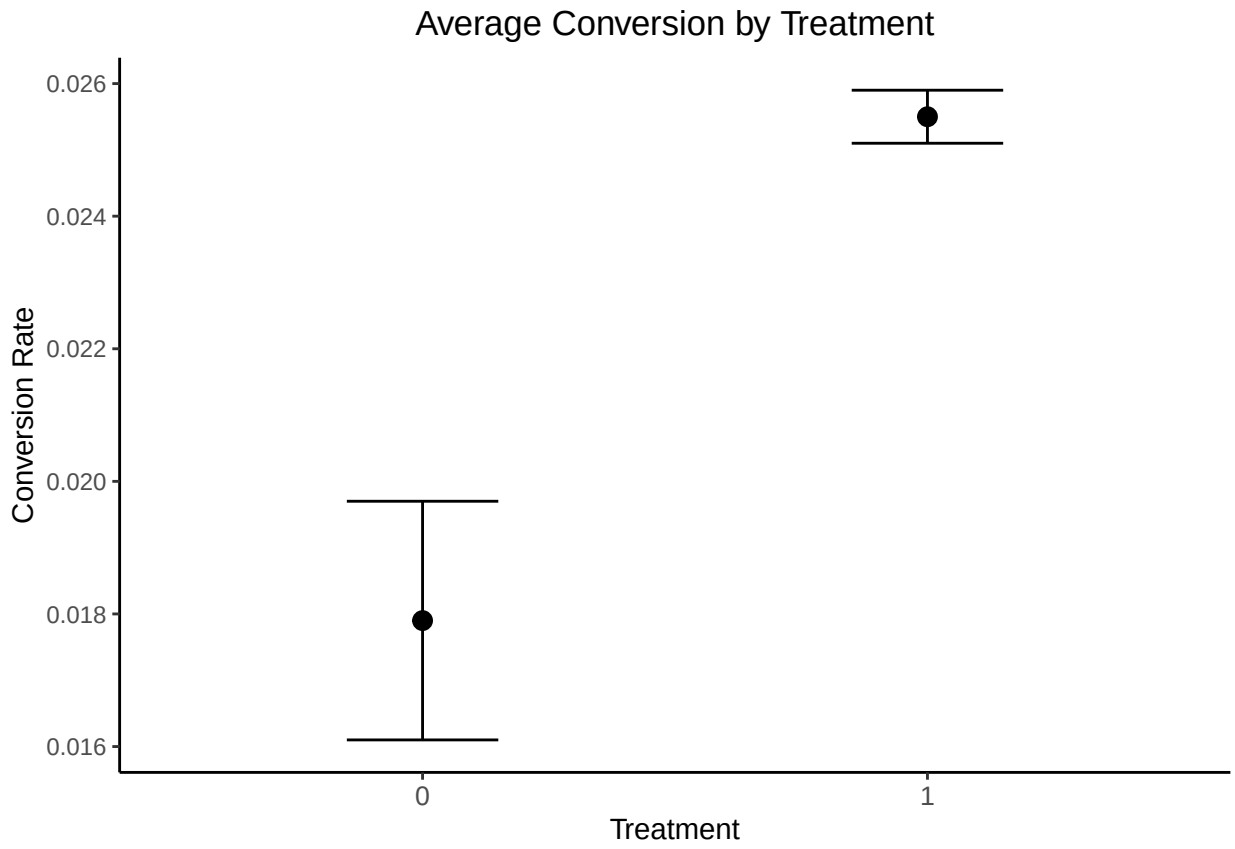
```r
summary <- rocketdata %>%
     mutate(test = as.factor(test)) %>%
     group_by(test) %>%
     summarise(n = length(user_id),
               avgconvert = round(mean(converted),4),
               error = round(sd(converted)/sqrt(n),4),
               lowerCI = round(avgconvert - 1.96*error,4),
               upperCI = round(avgconvert + 1.96*error,4))
kable(summary)
```

test	n	avgconvert	error	lowerCI	upperCI
0	23524	0.0179	9e-04	0.0161	0.0197
1	564577	0.0255	2e-04	0.0251	0.0259

```r
detach(rocketdata)
```

```r
attach(rocketdata)
summary %>%
     ggplot(aes(x=test)) +
     geom_point(aes(y = avgconvert), size = 3) +
     scale_shape_manual(values=c(15, 16)) +
     ggtitle("Average Conversion by Treatment") +
     ylab("Conversion Rate") + xlab("Treatment") +
     theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
           panel.background = element_blank(),axis.line = element_line(colour = "black"),
           axis.text.x= element_text(size = 10), legend.position=c(.5,.5),
           plot.title=element_text(hjust=.5))+
     geom_errorbar(aes(ymin = lowerCI,
                       ymax = upperCI), width = .3)+
     scale_color_manual(values=c("darkgrey","black"))
```

```
## Warning: A numeric ‘legend.position‘ argument in ‘theme()‘ was deprecated in ggplot2
## 3.5.0.
## i Please use the ‘legend.position.inside‘ argument of ‘theme()‘ instead.
## This warning is displayed once every 8 hours.
## Call ‘lifecycle::last_lifecycle_warnings()‘ to see where this warning was
## generated.
```




```
detach(rocketdata)
#Our confidence intervals for the control group and our treatment group show that we are 95% certain of
```

```
treatment_effect <- matrix(NA, ncol = 3, nrow = 2)
colnames(treatment_effect) <- c("Treatment Effect", "Lower 95% CI", "Upper 95% CI")
rownames(treatment_effect) <- c("Treatment", "Control Mean")
effects <- c(summary$avgconvert[2]-summary$avgconvert[1], summary$avgconvert[1])
error_treatment_effect <- c(sqrt(summary$error[1]^2+summary$error[2]^2), NA)
CIlower <- effects-1.96*error_treatment_effect
CIupper <- effects+1.96*error_treatment_effect
treatment_effect[,1] <- round(effects,4)
treatment_effect[,2] <- round(CIlower,4)
treatment_effect[,3] <- round(CIupper,4)
kable(treatment_effect)
```

	Treatment Effect	Lower 95% CI	Upper 95% CI
Treatment	0.0076	0.0058	0.0094
Control Mean	0.0179	NA	NA

```
attach(rocketdata)
controldata <- rocketdata[ which(rocketdata$test == 0),]
summary_control = controldata %>%
     mutate(tot_impr_decile = as.factor(tot_impr_decile)) %>%
```

```
     group_by(tot_impr_decile) %>%
     summarise(n = length(user_id),
               mean.conversion = round(mean(converted),4),
               error.conversion = round(sd(converted)/sqrt(n),4),
               LCI.conversion = round(mean.conversion - 1.96*error.conversion,4),
               UCI.conversion = round(mean.conversion + 1.96*error.conversion,4))
kable(summary_control)
```

tot_impr_decile	n	mean.conversion	error.conversion	LCI.conversion	UCI.conversion
1	4224	0.0014	0.0006	0.0002	0.0026
2	1333	0.0030	0.0015	0.0001	0.0059
3	2304	0.0052	0.0015	0.0023	0.0081
4	2490	0.0056	0.0015	0.0027	0.0085
5	2250	0.0067	0.0017	0.0034	0.0100
6	1734	0.0081	0.0021	0.0040	0.0122
7	2662	0.0139	0.0023	0.0094	0.0184
8	1868	0.0198	0.0032	0.0135	0.0261
9	2234	0.0345	0.0039	0.0269	0.0421
10	2425	0.0841	0.0056	0.0731	0.0951

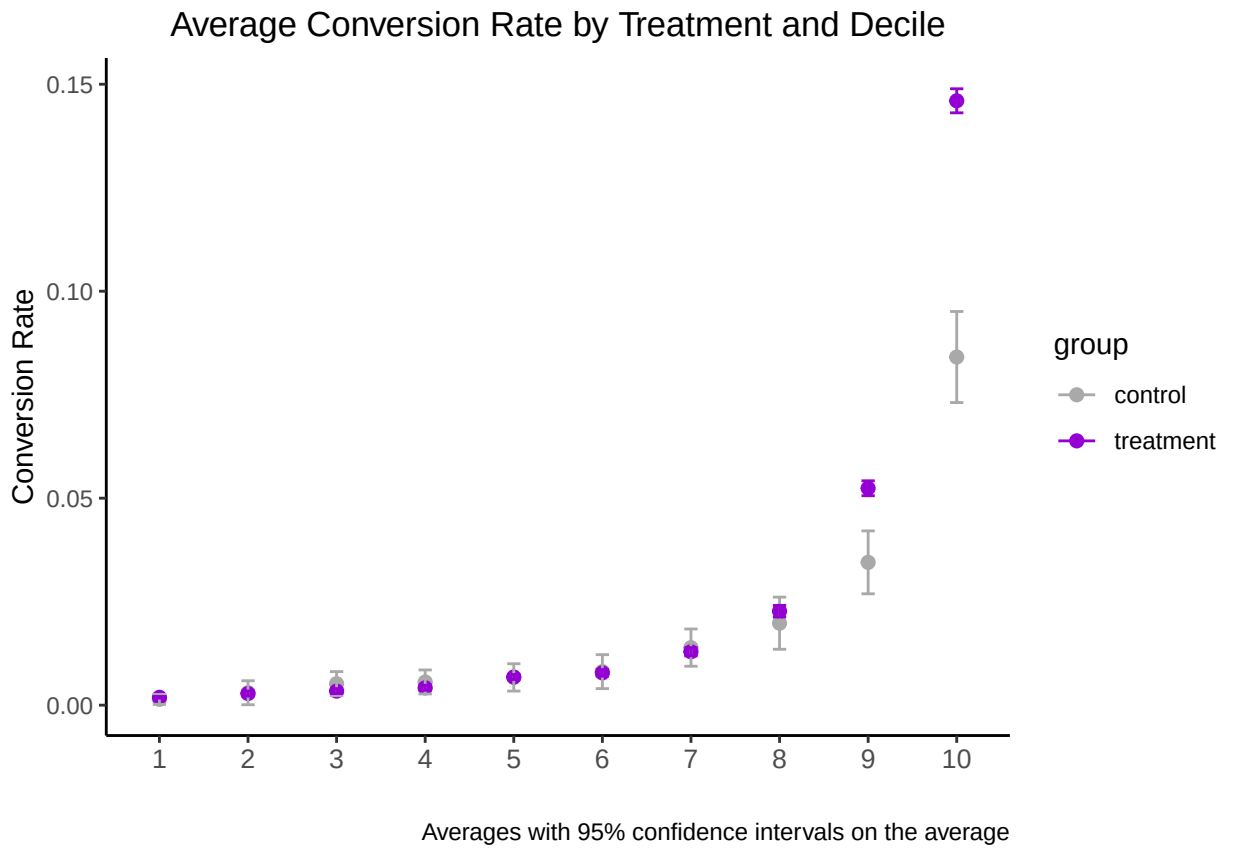
```
detach(rocketdata)
```

```
attach(rocketdata)
treatmentdata <- rocketdata[ which(rocketdata$test == 1),]
summary_treatment = treatmentdata %>%
     mutate(tot_impr_decile = as.factor(tot_impr_decile)) %>%
     group_by(tot_impr_decile) %>%
     summarise(n = length(user_id),
               mean.conversion.treat = round(mean(converted),4),
               error.conversion.treat = round(sd(converted)/sqrt(n),4),
               LCI.conversion.treat = round(mean.conversion.treat - 1.96*error.conversion.treat,4),
               UCI.conversion.treat = round(mean.conversion.treat + 1.96*error.conversion.treat,4))
kable(summary_treatment)
```

tot_impr_decile	n	mean.conversion.treat	error.conversion.treat	LCI.conversion.treat	UCI.conversion.treat
1	92209	0.0019	0.0001	0.0017	0.0021
2	27328	0.0028	0.0003	0.0022	0.0034
3	50425	0.0034	0.0003	0.0028	0.0040
4	56051	0.0042	0.0003	0.0036	0.0048
5	60882	0.0068	0.0003	0.0062	0.0074
6	56368	0.0078	0.0004	0.0070	0.0086
7	61873	0.0129	0.0005	0.0119	0.0139
8	47226	0.0227	0.0007	0.0213	0.0241
9	57194	0.0524	0.0009	0.0506	0.0542
10	55021	0.1460	0.0015	0.1431	0.1489

```
detach(rocketdata)
```

```r
attach(rocketdata)
color <- c("control"="darkgrey", "treatment"="darkviolet")
ggplot(NULL,aes(x=tot_impr_decile)) +
     geom_point(data=summary_control,aes(y = mean.conversion, color = "control"), size = 2) +
     geom_point(data=summary_treatment, aes(y = mean.conversion.treat, color = "treatment"), size = 2) +
     scale_shape_manual(values=c(15, 16)) +
     labs(
         title = "Average Conversion Rate by Treatment and Decile",
         caption = "Averages with 95% confidence intervals on the average"
     )+
     ylab("Conversion Rate") +
     scale_x_discrete(labels=c("0" = "Control", "1" = "1")) +
     xlab("")+
     theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
           panel.background = element_blank(),axis.line = element_line(colour = "black"),
           axis.text.x= element_text(size = 10), legend.position=,
           plot.title=element_text(hjust=.5))+
     geom_errorbar(data=summary_control,aes(ymin = LCI.conversion,
                                    ymax = UCI.conversion, color = "control"), width = .15)+
     geom_errorbar(data=summary_treatment,aes(ymin = LCI.conversion.treat,
                                        ymax = UCI.conversion.treat, color = "treatment"), width = .15
     scale_color_manual(name="group",values=color)
```




```r
#This plot shows us that the bottom 50% of people targeted by ads all have similar conversion rates reg
```