Studying the Impact of Virtual Reality on Sports: An Experimental Study

Author: Anusha Ronaki, Lokendra Singh Badgujar, Mehul Agarwal, Prateek Naharia Siddharth Bookinkere, Sonal Kaur.

You can add options to executable code like this

```
dataset <- fread('DART.csv')
colnames(dataset)[6] <- "frequency"
colnames(dataset)[7] <- "head_tail"
colnames(dataset)[8] <- "test"
colnames(dataset)[9] <- "throw1"
colnames(dataset)[10] <- "throw2"
colnames(dataset)[11] <- "throw3"

for (col in c("Degree", "Gender", "Age", "frequency", "head_tail")) {
  dataset[[col]] <- as.factor(dataset[[col]])
}
dataset
```

```
                Email                  Name    Degree Gender Age frequency
 1:     gcamp@bu.edu        Gavin Campbel UnderGrad      M  19         1
 2:     helia@bu.edu           helia zhao UnderGrad      F  20         1
 3:  sydtrues@bu.edu     sydney truesdale UnderGrad      F  20         1
 4:    lbahri@bu.edu           lili bahri UnderGrad      F  20         0
 5:  abbyslat@bu.edu        abby slatalla UnderGrad      F  21         0
 6:      gkap@bu.edu                 gary UnderGrad      M  21         1
 7:     cohsu@bu.edu              courtney      Grad      F  28         2
 8:   smritik@bu.edu                Smriri UnderGrad      F  20         1
 9:  lolteanu@bu.edu          Lucas Oltea UnderGrad      M  21         2
10:     nncha@bu.edu                  Nat      Grad      F  29         0
11:  shreyass@bu.edu               Shreyas      Grad      M  30         0
12:    sduddy@bu.edu                 Daisy      Grad      F  31         0
13: ianthomas@bu.edu                   Ian UnderGrad      M  19         1
```

14:	hychang@bu.edu	Howard	Grad	M	24	1
15:	xykang@bu.edu	xiyao	UnderGrad	F	19	0
16:	lrohrer@bu.edu	lisa	Others	F	51	1
17:	mgrubin@bu.edu	melissa	Others	F	59	1
18:	fgermain@bu.edu	Fiona	Others	F	54	0
19:	msa2714@bu.edu	Muhammad	UnderGrad	M	22	2
20:	sarmadk@bu.edu	Sarmad	Grad	M	26	1
21:	karismaa@bu.edu	Karishma. arora	Grad	F	25	0
22:	pallavig@bu.edu	Pallavi Gottumukkala	Grad	F	22	0
23:	marekm@bu.edu	Marek Michalak	Grad	M	37	1
24:	zhxie@bu.edu	Zhenhuan	Grad	M	27	1
25:	syedagq@bu.edu	Ghazal	UnderGrad	F	21	1
26:	maurius@bu.edu	Maurisio	Grad	M	32	0
27:	jabidemi@bu.edu	Sam	Grad	M	33	0
28:	yxcheng@bu.edu	Claire	Grad	F	24	1
29:	araspall@bu.edu	abby	Others	F	43	1
30:	chenz23@bu.edu	David	Grad	M	24	0
31:	asher25@bu.edu	Asher	UnderGrad	M	19	1
32:	bbhardw@bu.edu	Bhagirath Bhardwaj	Grad	M	25	1
33:	aheger@bu.edu	Alex	Grad	M	27	0
34:	anishp@bu.edu	Anish	Grad	M	26	0
35:	normanb@bu.edu	Norm	Others	M	57	2
36:	makaylar@bu.edu	Makayla	UnderGrad	F	18	0
37:	arusi7@bu.edu	Arusi	Grad	F	22	0
38:	martinaw@bu.edu	Martina	Grad	F	27	1
39:	rlee03@bu.edu	Ryan	UnderGrad	M	19	0
40:	camina@bu.edu	Carlos	Grad	M	28	0
41:	jsfajard@bu.edu	Juan	Grad	M	34	1
42:	snaman@bu.edu	Naman Singhal	UnderGrad	M	19	0
43:	pchai@bu.edu	Pejae	Grad	M	28	0
44:	lanwar99@bu>edu	LINA	Grad	F	23	1
45:	sym@bu.edu	Morty	Grad	M	22	1
46:	karins@bu.edu	Karina	PHD	F	31	1
47:	zebedeea@bu.edu	Zeb	Grad	M	23	1
48:	akakkar@bu.edu	Aman	Grad	M	23	0
49:	mihirsw8@bu.edu	Mihir	Grad	M	23	1
50:	annan923@bu.edu	Kylin	UnderGrad	M	23	1
51:	wjordan@bu.edu	Jordan wen	Grad	M	22	1
52:	hagosto@bu.edu	hector	Grad	M	39	1
53:	lrab@bu.edu	Louie	Grad	M	26	1
54:	goodrid@bu.edu	annie	Grad	F	27	1
55:	devnaik@bu.edu	Dev	Grad	M	26	1
56:	saltc18@bu.edu	Salil	Grad	M	24	1
57:	adwanj@bu.edu	Alan Wang	Grad	M	27	1
58:	rytaher@bu.edu	Ryan	UnderGrad	M	22	1

```
59:  pmatta01@bu.edu              Puneet      Grad      M  31         1
60:  dipankar@bu.edu            Dipankar      Grad      M  34         1
61:     Ramit@bu.edu               Ramit      Grad      M  28         0
62:    kamika@bu.edu              Kamika      Grad      F  31         0
63:  bhavikab@bu.edu             Bhavika      Grad      F  27         0
64:    paulnp@bu.edu                Noor      Grad      F  30         0
65:  lewisg24@bu.edu               Grace UnderGrad      F  21         2
66:    cearaw@bu.edu               Ceara UnderGrad      F  21         0
67:      aile@bu.edu              Ai Le UnderGrad      F  20         2
68:  valeriee@bu.edu          Valarie Lo UnderGrad      F  20         2
69:    jovena@bu.edu           Elizabeth      Grad      F  20         0
70:  shubhamt@bu.edu       Shubham Tyagi      Grad      M  28         1
71:   sandipr@bu.edu              Sandip      Grad      M  30         1
72:   htagerc@bu.edu               Harry UnderGrad      M  21         1
               Email                Name    Degree Gender Age frequency
    head_tail test throw1 throw2 throw3
 1:         T    1      1      3      0
 2:         H    0      1      1      0
 3:         T    1      0      3      3
 4:         T    1      1      1      3
 5:         T    1      3      0      3
 6:         H    0      1      0      3
 7:         T    1      3      1      0
 8:         H    0      0      0      0
 9:         H    0      1      3      1
10:         H    0      3      1      1
11:         H    0      0      1      3
12:         T    1      0      3     10
13:         T    1      1      1     10
14:         T    1      0      3      3
15:         H    0      1      1      1
16:         T    1      3      3      3
17:         H    0      0      3      3
18:         T    1      3      0      3
19:         H    0      1      0      0
20:         H    0      0      1      3
21:         T    1      1      3      0
22:         H    0      0      3      3
23:         T    1      1      3      0
24:         H    0      3      1      3
25:         H    0      1      3      3
26:         H    0      1      0      3
27:         H    0      3      1      0
28:         T    1      0      1      3
29:         T    1      0      3      1
```

	head_tail	test	throw1	throw2	throw3
30:	T	1	3	3	3
31:	T	1	3	3	3
32:	H	0	10	0	0
33:	T	1	3	3	3
34:	H	0	0	3	3
35:	H	0	0	1	3
36:	T	1	0	1	3
37:	H	0	0	1	1
38:	T	1	0	1	0
39:	T	1	0	0	0
40:	T	1	0	3	0
41:	T	1	1	3	3
42:	H	0	0	3	1
43:	H	0	3	1	0
44:	H	0	0	0	1
45:	H	0	3	3	3
46:	T	1	3	3	3
47:	T	1	0	3	1
48:	H	0	3	3	3
49:	T	1	0	1	1
50:	H	0	3	3	0
51:	T	1	0	1	1
52:	H	0	3	0	3
53:	T	1	1	3	3
54:	T	1	1	0	0
55:	T	1	0	1	0
56:	T	1	1	3	3
57:	H	0	1	3	3
58:	H	0	0	0	3
59:	T	1	0	3	1
60:	T	1	0	3	0
61:	T	1	1	1	1
62:	H	0	1	1	3
63:	H	0	3	0	3
64:	H	0	3	3	1
65:	H	0	3	3	3
66:	H	0	0	1	1
67:	H	0	0	1	0
68:	H	0	3	1	0
69:	H	0	0	0	0
70:	T	1	3	3	0
71:	T	1	0	3	3
72:	T	1	3	3	3

```r
dataset$total_score <- dataset$throw1 + dataset$throw2 + dataset$throw3
dataset$accuracy <- dataset$total_score / 30
dataset$accuracy <- round(dataset$accuracy, 5)
data_treatment <- dataset[test == 1]
data_control <- dataset[test == 0]

mean_converted_test <- mean(data_treatment$accuracy)
mean_converted_control <- mean(data_control$accuracy)
ATE_hat <- mean_converted_test - mean_converted_control

print(paste0('Mean for Treatment: ',mean_converted_test))
```

```
[1] "Mean for Treatment: 0.1787025"
```

```r
print(paste0('Mean for Control: ',mean_converted_control))
```

```
[1] "Mean for Control: 0.154628611111111"
```

```r
print(paste0('ATE HAT:',ATE_hat))
```

```
[1] "ATE HAT:0.0240738888888889"
```

```r
mean(data_treatment$accuracy)
```

```
[1] 0.1787025
```

```r
variance_treat <- var(data_treatment$accuracy)
variance_cnt <- var(data_control$accuracy)
variance_treat
```

```
[1] 0.01061291
```

```r
variance_cnt
```

```
[1] 0.007374748
```

```r
summary(dataset)
```

```
    Email               Name                Degree   Gender      Age
 Length:72          Length:72          Grad      :43   F:31   20     : 7
 Class :character   Class :character   Others    : 5   M:41   21     : 7
 Mode  :character   Mode  :character   PHD       : 1          19     : 6
                                       UnderGrad:23           22     : 6
                                                              27     : 6
```

```
                                                          23     : 5
                                                          (Other):35
 frequency head_tail      test          throw1           throw2
 0:27      H:36      Min.   :0.0   Min.   : 0.000   Min.   :0.00
 1:38      T:36      1st Qu.:0.0   1st Qu.: 0.000   1st Qu.:1.00
 2: 7                Median :0.5   Median : 1.000   Median :1.00
                     Mean   :0.5   Mean   : 1.319   Mean   :1.75
                     3rd Qu.:1.0   3rd Qu.: 3.000   3rd Qu.:3.00
                     Max.   :1.0   Max.   :10.000   Max.   :3.00

     throw3        total_score    accuracy
 Min.   : 0.000   Min.   : 0   Min.   :0.0000
 1st Qu.: 0.000   1st Qu.: 3   1st Qu.:0.1000
 Median : 3.000   Median : 4   Median :0.1333
 Mean   : 1.931   Mean   : 5   Mean   :0.1667
 3rd Qu.: 3.000   3rd Qu.: 7   3rd Qu.:0.2333
 Max.   :10.000   Max.   :13   Max.   :0.4333
```

```
summary(data_control)
```

```
    Email               Name                Degree   Gender      Age
 Length:36          Length:36          Grad     :20   F:17   20     : 5
 Class :character   Class :character   Others   : 2   M:19   21     : 5
 Mode  :character   Mode  :character   PHD      : 0          22     : 5
                                       UnderGrad:14          23     : 3
                                                             27     : 3
                                                             19     : 2
                                                             (Other):13
 frequency head_tail      test         throw1           throw2
 0:16      H:36      Min.   :0   Min.   : 0.000   Min.   :0.000
 1:14      T: 0      1st Qu.:0   1st Qu.: 0.000   1st Qu.:0.000
 2: 6                Median :0   Median : 1.000   Median :1.000
                     Mean   :0   Mean   : 1.528   Mean   :1.389
                     3rd Qu.:0   3rd Qu.: 3.000   3rd Qu.:3.000
                     Max.   :0   Max.   :10.000   Max.   :3.000

     throw3       total_score        accuracy
 Min.   :0.000   Min.   : 0.000   Min.   :0.0000
 1st Qu.:0.000   1st Qu.: 3.000   1st Qu.:0.1000
 Median :2.000   Median : 4.000   Median :0.1333
 Mean   :1.722   Mean   : 4.639   Mean   :0.1546
 3rd Qu.:3.000   3rd Qu.: 6.000   3rd Qu.:0.2000
 Max.   :3.000   Max.   :10.000   Max.   :0.3333
```

```
summary(data_treatment)
```

```
    Email               Name                Degree   Gender      Age
 Length:36          Length:36          Grad     :23   F:14   19     : 4
 Class :character   Class :character   Others   : 3   M:22   24     : 4
 Mode  :character   Mode  :character   PHD      : 1          28     : 4
                                       UnderGrad: 9          27     : 3
                                                             31     : 3
                                                             20     : 2
                                                             (Other):16
 frequency head_tail      test       throw1          throw2
 0:11      H: 0      Min.   :1   Min.   :0.000   Min.   :0.000
 1:24      T:36      1st Qu.:1   1st Qu.:0.000   1st Qu.:1.000
 2: 1                Median :1   Median :1.000   Median :3.000
                     Mean   :1   Mean   :1.111   Mean   :2.111
                     3rd Qu.:1   3rd Qu.:3.000   3rd Qu.:3.000
                     Max.   :1   Max.   :3.000   Max.   :3.000

     throw3        total_score        accuracy
 Min.   : 0.000   Min.   : 0.000   Min.   :0.0000
 1st Qu.: 0.000   1st Qu.: 3.750   1st Qu.:0.1250
 Median : 3.000   Median : 4.500   Median :0.1500
 Mean   : 2.139   Mean   : 5.361   Mean   :0.1787
 3rd Qu.: 3.000   3rd Qu.: 7.000   3rd Qu.:0.2333
 Max.   :10.000   Max.   :13.000   Max.   :0.4333
```

```
t.test(dataset[test == 1, accuracy], dataset[test == 0, accuracy])
```

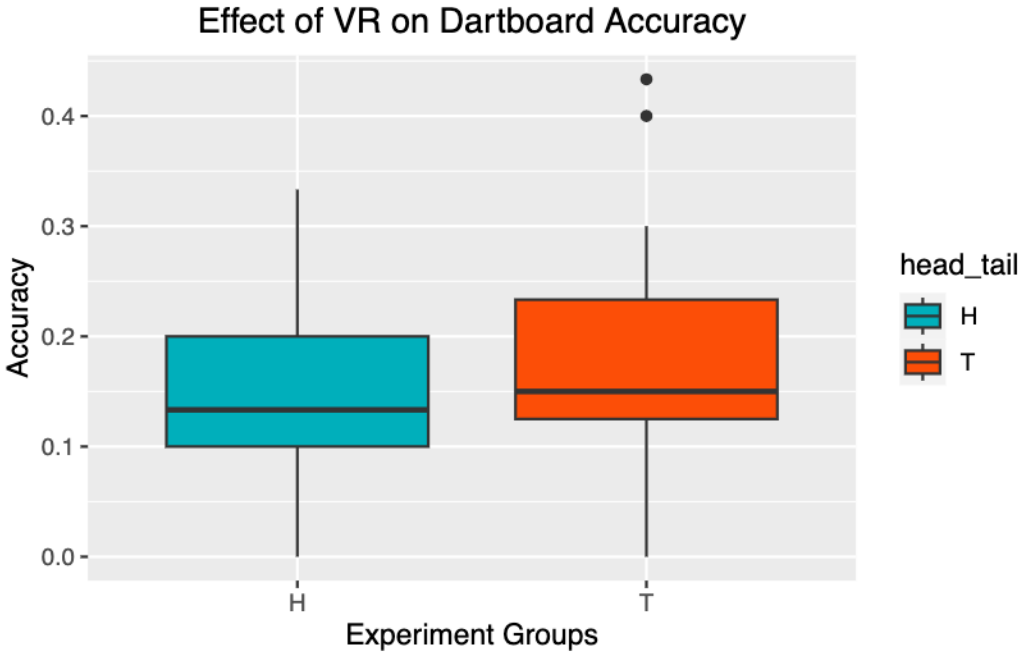
```
    Welch Two Sample t-test

data:  dataset[test == 1, accuracy] and dataset[test == 0, accuracy]
t = 1.077, df = 67.803, p-value = 0.2853
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.02053320  0.06868098
sample estimates:
mean of x mean of y
0.1787025 0.1546286
```

```
str(dataset)
```

```
Classes 'data.table' and 'data.frame':  72 obs. of  13 variables:
```

```
 $ Email      : chr  "gcamp@bu.edu" "helia@bu.edu" "sydtrues@bu.edu" "lbahri@bu.edu" ...
 $ Name       : chr  "Gavin Campbel" "helia zhao" "sydney truesdale" "lili bahri" ...
 $ Degree     : Factor w/ 4 levels "Grad","Others",..: 4 4 4 4 4 4 1 4 4 1 ...
 $ Gender     : Factor w/ 2 levels "F","M": 2 1 1 1 1 2 1 1 2 1 ...
 $ Age        : Factor w/ 24 levels "18","19","20",..: 2 3 3 3 4 4 11 3 4 12 ...
 $ frequency  : Factor w/ 3 levels "0","1","2": 2 2 2 1 1 2 3 2 3 1 ...
 $ head_tail  : Factor w/ 2 levels "H","T": 2 1 2 2 2 1 2 1 1 1 ...
 $ test       : int  1 0 1 1 1 0 1 0 0 0 ...
 $ throw1     : int  1 1 0 1 3 1 3 0 1 3 ...
 $ throw2     : int  3 1 3 1 0 0 1 0 3 1 ...
 $ throw3     : int  0 0 3 3 3 3 0 0 1 1 ...
 $ total_score: int  4 2 6 5 6 4 4 0 5 5 ...
 $ accuracy   : num  0.1333 0.0667 0.2 0.1667 0.2 ...
 - attr(*, ".internal.selfref")=<externalptr>
 - attr(*, "index")= int(0)
  ..- attr(*, "__test")= int [1:72] 2 6 8 9 10 11 15 17 19 20 ...
```

```
ggplot(data = dataset, aes(x = head_tail, y = accuracy, fill = head_tail)) +
  geom_boxplot() +
  ggtitle("Effect of VR on Dartboard Accuracy") +
  xlab("Experiment Groups") +
  ylab("Accuracy") +
  scale_fill_manual(values = c("#00AFBB", "#FC4E07")) +
  theme(plot.title = element_text(hjust = 0.5))
```



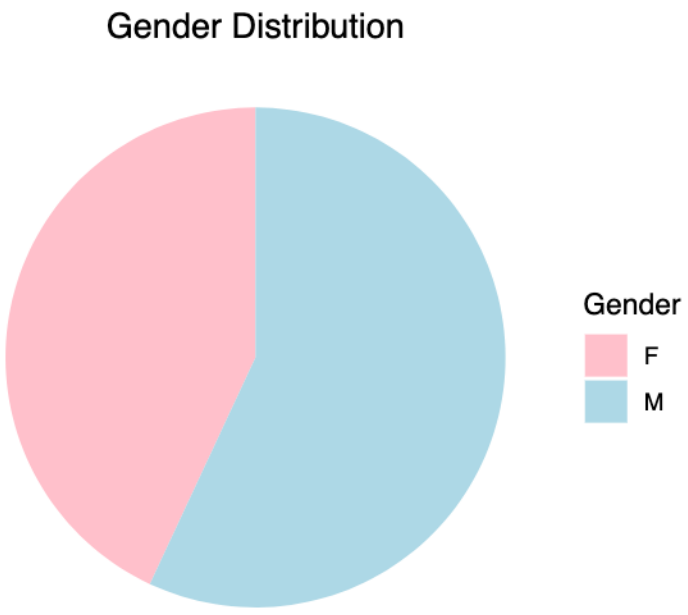

```
gender_data <- subset(dataset, select=c(Gender))
```

```r
# Count the frequency of each gender
gender_count <- table(gender_data)
gender_count
```

```
Gender
 F  M
31 41
```

```r
# Create a data frame with the gender labels and counts
gender_df <- data.frame(Gender=names(gender_count), Count=gender_count)

# Create the pie chart
ggplot(gender_df, aes(x="", y=gender_count, fill=Gender)) +
  geom_bar(stat="identity", width=1) +
  coord_polar(theta="y") +
  scale_fill_manual(values=c("#FFC0CB", "#ADD8E6")) +
  theme_void() +
  labs(title="Gender Distribution") +
  theme(plot.title=element_text(hjust=0.5))
```

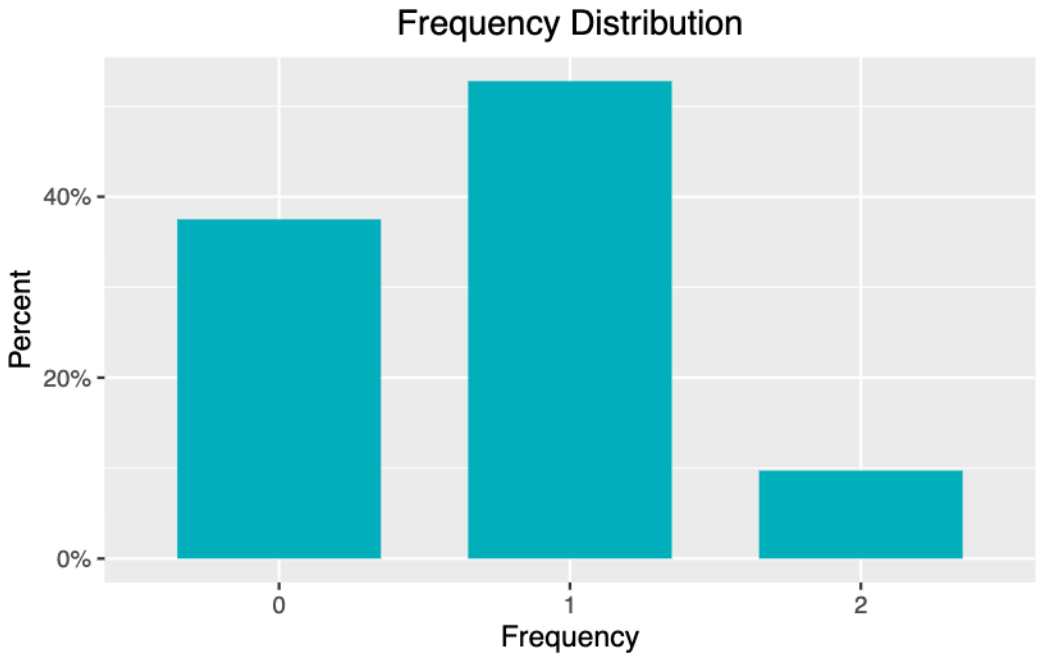
```
Don't know how to automatically pick scale for object of type <table>.
Defaulting to continuous.
```



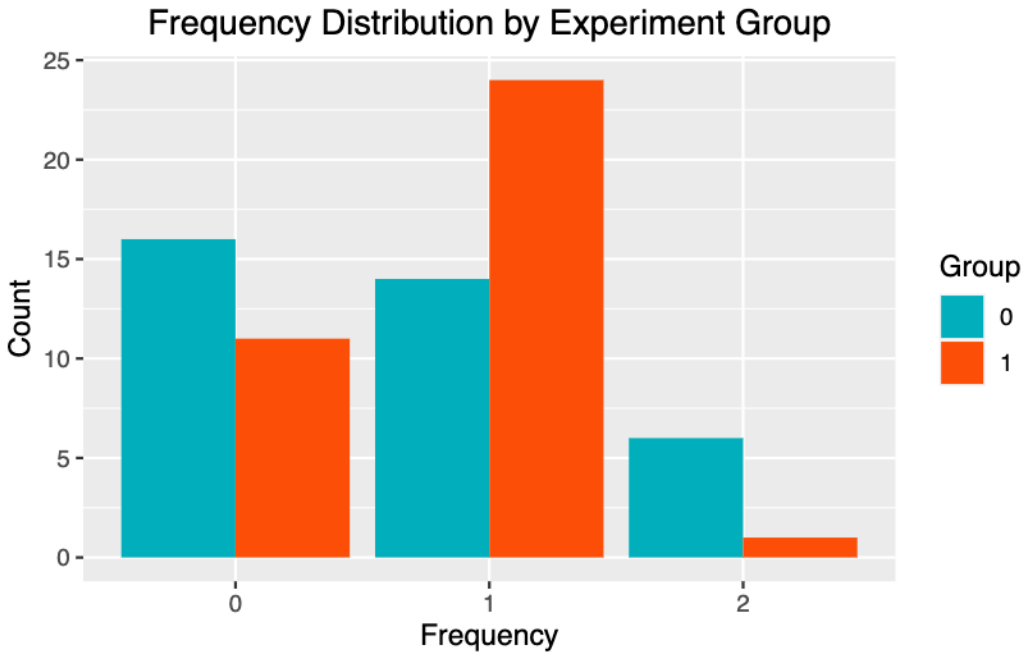

```r
ggplot(dataset, aes(x=frequency)) +
  geom_bar(aes(y = (..count..)/sum(..count..)), width = 0.7, fill = "#00AFBB") +
  scale_y_continuous(labels = scales::percent_format()) +
```

```
  ggtitle("Frequency Distribution") +
  xlab("Frequency") +
  ylab("Percent") +
  theme(plot.title = element_text(hjust = 0.5))
```

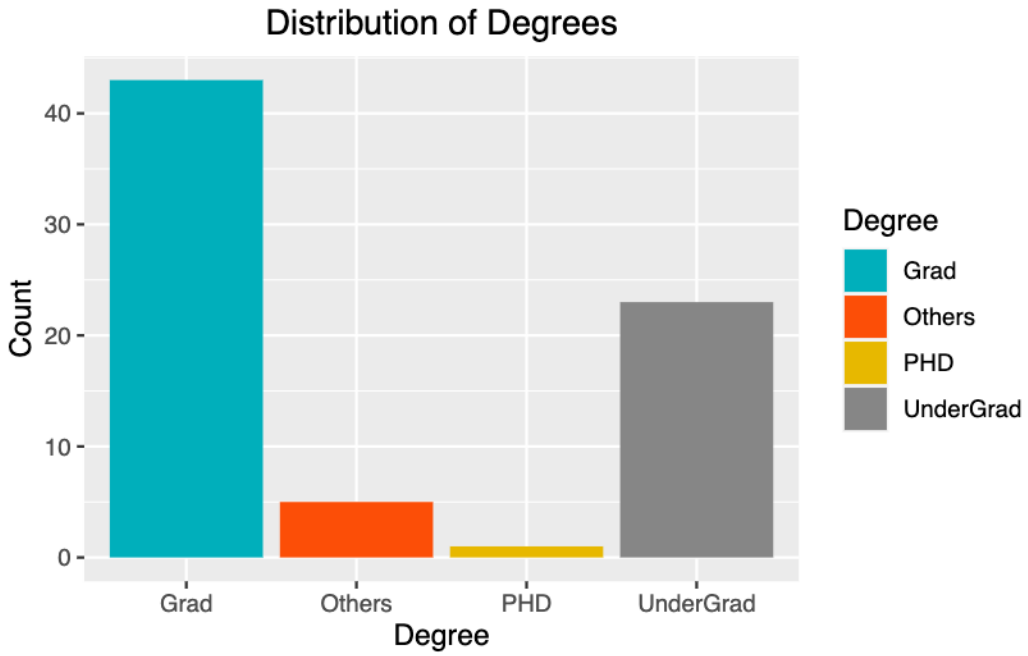
```
Warning: The dot-dot notation (`..count..`) was deprecated in ggplot2 3.4.0.
i Please use `after_stat(count)` instead.
```




```
ggplot(data = dataset, aes(x = frequency, fill = as.factor(test))) +
  geom_bar(position = "dodge") +
  scale_fill_manual(values = c("#00AFBB", "#FC4E07"), name = "Group") +
  ggtitle("Frequency Distribution by Experiment Group") +
  xlab("Frequency") +
  ylab("Count") +
  theme(plot.title = element_text(hjust = 0.5))
```




```r
library(ggplot2)

ggplot(data = dataset, aes(x = Degree, fill = Degree)) +
  geom_bar() +
  ggtitle("Distribution of Degrees") +
  xlab("Degree") +
  ylab("Count") +
  scale_fill_manual(values = c("#00AFBB", "#FC4E07",
                               "#E7B800", "#868686",
                               "#FF7F0F", "#8DA0CB")) +
  theme(plot.title = element_text(hjust = 0.5))
```




```
se <- sqrt(var(data_treatment$accuracy) / length(data_treatment$accuracy) + var(data_control
print(paste0("Standard Error:",se))
```

```
[1] "Standard Error:0.0223530130440455"
```

```
#Creating subset for treatment and control group
data_treatment_subset <- subset(dataset, test == 1)
data_control_subset <- subset(dataset, test == 0)

model_reg <- lm(accuracy ~ test, data = dataset)
summary(model_reg)
```

```
Call:
lm(formula = accuracy ~ test, data = dataset)

Residuals:
     Min       1Q   Median       3Q      Max
-0.17870 -0.05463 -0.02130  0.05463  0.25463

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.15463    0.01581   9.783 9.87e-15 ***
test         0.02407    0.02235   1.077    0.285
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.09484 on 70 degrees of freedom
Multiple R-squared:  0.0163,    Adjusted R-squared:  0.002247
F-statistic:  1.16 on 1 and 70 DF,  p-value: 0.2852
```

```r
model_reg <- lm(throw2 ~ test, data = dataset)
summary(model_reg)
```

```

Call:
lm(formula = throw2 ~ test, data = dataset)

Residuals:
    Min      1Q  Median      3Q     Max
-2.1111 -1.1111 -0.3889  0.8889  1.6111

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.3889     0.1993   6.968 1.43e-09 ***
test          0.7222     0.2819   2.562   0.0126 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.196 on 70 degrees of freedom
Multiple R-squared:  0.08574,   Adjusted R-squared:  0.07268
F-statistic: 6.565 on 1 and 70 DF,  p-value: 0.01256
```

```r
model_reg <- lm(throw1 ~ test, data = dataset)
summary(model_reg)
```

```

Call:
lm(formula = throw1 ~ test, data = dataset)

Residuals:
    Min      1Q  Median      3Q     Max
-1.5278 -1.1111 -0.5278  1.4722  8.4722

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.5278     0.2735   5.586 4.15e-07 ***
test         -0.4167     0.3868  -1.077    0.285
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 1.641 on 70 degrees of freedom
Multiple R-squared:  0.01631,   Adjusted R-squared:  0.002253
F-statistic:  1.16 on 1 and 70 DF,  p-value: 0.2851
```

```
model_reg <- lm(throw3 ~ test, data = dataset)
summary(model_reg)
```

```

Call:
lm(formula = throw3 ~ test, data = dataset)

Residuals:
    Min      1Q  Median      3Q     Max
-2.1389 -1.7222  0.8611  1.2778  7.8611

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.7222     0.3197   5.387 9.09e-07 ***
test          0.4167     0.4521   0.922     0.36
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.918 on 70 degrees of freedom
Multiple R-squared:  0.01199,   Adjusted R-squared:  -0.002125
F-statistic: 0.8494 on 1 and 70 DF,  p-value: 0.3599
```

```
mean(dataset$throw1)
```

```
[1] 1.319444
```

```
mean(dataset$throw2)
```

```
[1] 1.75
```

```
mean(dataset$throw3)
```

```
[1] 1.930556
```

```
dataset$mean_allthrows <- dataset$total_score / 3
dataset
```

```
              Email                 Name    Degree Gender Age frequency
 1:     gcamp@bu.edu        Gavin Campbel UnderGrad      M  19         1
 2:     helia@bu.edu           helia zhao UnderGrad      F  20         1
```

3:	sydtrues@bu.edu	sydney truesdale	UnderGrad	F	20	1
4:	lbahri@bu.edu	lili bahri	UnderGrad	F	20	0
5:	abbyslat@bu.edu	abby slatalla	UnderGrad	F	21	0
6:	gkap@bu.edu	gary	UnderGrad	M	21	1
7:	cohsu@bu.edu	courtney	Grad	F	28	2
8:	smritik@bu.edu	Smriri	UnderGrad	F	20	1
9:	lolteanu@bu.edu	Lucas Oltea	UnderGrad	M	21	2
10:	nncha@bu.edu	Nat	Grad	F	29	0
11:	shreyass@bu.edu	Shreyas	Grad	M	30	0
12:	sduddy@bu.edu	Daisy	Grad	F	31	0
13:	ianthomas@bu.edu	Ian	UnderGrad	M	19	1
14:	hychang@bu.edu	Howard	Grad	M	24	1
15:	xykang@bu.edu	xiyao	UnderGrad	F	19	0
16:	lrohrer@bu.edu	lisa	Others	F	51	1
17:	mgrubin@bu.edu	melissa	Others	F	59	1
18:	fgermain@bu.edu	Fiona	Others	F	54	0
19:	msa2714@bu.edu	Muhammad	UnderGrad	M	22	2
20:	sarmadk@bu.edu	Sarmad	Grad	M	26	1
21:	karismaa@bu.edu	Karishma. arora	Grad	F	25	0
22:	pallavig@bu.edu	Pallavi Gottumukkala	Grad	F	22	0
23:	marekm@bu.edu	Marek Michalak	Grad	M	37	1
24:	zhxie@bu.edu	Zhenhuan	Grad	M	27	1
25:	syedagq@bu.edu	Ghazal	UnderGrad	F	21	1
26:	maurius@bu.edu	Maurisio	Grad	M	32	0
27:	jabidemi@bu.edu	Sam	Grad	M	33	0
28:	yxcheng@bu.edu	Claire	Grad	F	24	1
29:	araspall@bu.edu	abby	Others	F	43	1
30:	chenz23@bu.edu	David	Grad	M	24	0
31:	asher25@bu.edu	Asher	UnderGrad	M	19	1
32:	bbhardw@bu.edu	Bhagirath Bhardwaj	Grad	M	25	1
33:	aheger@bu.edu	Alex	Grad	M	27	0
34:	anishp@bu.edu	Anish	Grad	M	26	0
35:	normanb@bu.edu	Norm	Others	M	57	2
36:	makaylar@bu.edu	Makayla	UnderGrad	F	18	0
37:	arusi7@bu.edu	Arusi	Grad	F	22	0
38:	martinaw@bu.edu	Martina	Grad	F	27	1
39:	rlee03@bu.edu	Ryan	UnderGrad	M	19	0
40:	camina@bu.edu	Carlos	Grad	M	28	0
41:	jsfajard@bu.edu	Juan	Grad	M	34	1
42:	snaman@bu.edu	Naman Singhal	UnderGrad	M	19	0
43:	pchai@bu.edu	Pejae	Grad	M	28	0
44:	lanwar99@bu>edu	LINA	Grad	F	23	1
45:	sym@bu.edu	Morty	Grad	M	22	1
46:	karins@bu.edu	Karina	PHD	F	31	1
47:	zebedeea@bu.edu	Zeb	Grad	M	23	1

```
48:   akakkar@bu.edu                Aman      Grad      M  23         0
49:  mihirsw8@bu.edu               Mihir      Grad      M  23         1
50:  annan923@bu.edu               Kylin UnderGrad      M  23         1
51:   wjordan@bu.edu          Jordan wen      Grad      M  22         1
52:   hagosto@bu.edu              hector      Grad      M  39         1
53:      lrab@bu.edu               Louie      Grad      M  26         1
54:   goodrid@bu.edu               annie      Grad      F  27         1
55:   devnaik@bu.edu                 Dev      Grad      M  26         1
56:   saltc18@bu.edu               Salil      Grad      M  24         1
57:    adwanj@bu.edu          Alan Wang      Grad      M  27         1
58:   rytaher@bu.edu                Ryan UnderGrad      M  22         1
59:  pmatta01@bu.edu              Puneet      Grad      M  31         1
60:  dipankar@bu.edu             Dipankar      Grad      M  34         1
61:     Ramit@bu.edu               Ramit      Grad      M  28         0
62:    kamika@bu.edu              Kamika      Grad      F  31         0
63:  bhavikab@bu.edu             Bhavika      Grad      F  27         0
64:    paulnp@bu.edu                Noor      Grad      F  30         0
65:  lewisg24@bu.edu               Grace UnderGrad      F  21         2
66:    cearaw@bu.edu               Ceara UnderGrad      F  21         0
67:      aile@bu.edu               Ai Le UnderGrad      F  20         2
68:  valeriee@bu.edu          Valarie Lo UnderGrad      F  20         2
69:    jovena@bu.edu           Elizabeth      Grad      F  20         0
70:  shubhamt@bu.edu       Shubham Tyagi      Grad      M  28         1
71:   sandipr@bu.edu              Sandip      Grad      M  30         1
72:   htagerc@bu.edu               Harry UnderGrad      M  21         1
              Email                Name    Degree Gender Age frequency
    head_tail test throw1 throw2 throw3 total_score accuracy mean_allthrows
 1:         T    1      1      3      0           4  0.13333      1.3333333
 2:         H    0      1      1      0           2  0.06667      0.6666667
 3:         T    1      0      3      3           6  0.20000      2.0000000
 4:         T    1      1      1      3           5  0.16667      1.6666667
 5:         T    1      3      0      3           6  0.20000      2.0000000
 6:         H    0      1      0      3           4  0.13333      1.3333333
 7:         T    1      3      1      0           4  0.13333      1.3333333
 8:         H    0      0      0      0           0  0.00000      0.0000000
 9:         H    0      1      3      1           5  0.16667      1.6666667
10:         H    0      3      1      1           5  0.16667      1.6666667
11:         H    0      0      1      3           4  0.13333      1.3333333
12:         T    1      0      3     10          13  0.43333      4.3333333
13:         T    1      1      1     10          12  0.40000      4.0000000
14:         T    1      0      3      3           6  0.20000      2.0000000
15:         H    0      1      1      1           3  0.10000      1.0000000
16:         T    1      3      3      3           9  0.30000      3.0000000
17:         H    0      0      3      3           6  0.20000      2.0000000
18:         T    1      3      0      3           6  0.20000      2.0000000
```

19:	H	0	1	0	0	1	0.03333	0.3333333
20:	H	0	0	1	3	4	0.13333	1.3333333
21:	T	1	1	3	0	4	0.13333	1.3333333
22:	H	0	0	3	3	6	0.20000	2.0000000
23:	T	1	1	3	0	4	0.13333	1.3333333
24:	H	0	3	1	3	7	0.23333	2.3333333
25:	H	0	1	3	3	7	0.23333	2.3333333
26:	H	0	1	0	3	4	0.13333	1.3333333
27:	H	0	3	1	0	4	0.13333	1.3333333
28:	T	1	0	1	3	4	0.13333	1.3333333
29:	T	1	0	3	1	4	0.13333	1.3333333
30:	T	1	3	3	3	9	0.30000	3.0000000
31:	T	1	3	3	3	9	0.30000	3.0000000
32:	H	0	10	0	0	10	0.33333	3.3333333
33:	T	1	3	3	3	9	0.30000	3.0000000
34:	H	0	0	3	3	6	0.20000	2.0000000
35:	H	0	0	1	3	4	0.13333	1.3333333
36:	T	1	0	1	3	4	0.13333	1.3333333
37:	H	0	0	1	1	2	0.06667	0.6666667
38:	T	1	0	1	0	1	0.03333	0.3333333
39:	T	1	0	0	0	0	0.00000	0.0000000
40:	T	1	0	3	0	3	0.10000	1.0000000
41:	T	1	1	3	3	7	0.23333	2.3333333
42:	H	0	0	3	1	4	0.13333	1.3333333
43:	H	0	3	1	0	4	0.13333	1.3333333
44:	H	0	0	0	1	1	0.03333	0.3333333
45:	H	0	3	3	3	9	0.30000	3.0000000
46:	T	1	3	3	3	9	0.30000	3.0000000
47:	T	1	0	3	1	4	0.13333	1.3333333
48:	H	0	3	3	3	9	0.30000	3.0000000
49:	T	1	0	1	1	2	0.06667	0.6666667
50:	H	0	3	3	0	6	0.20000	2.0000000
51:	T	1	0	1	1	2	0.06667	0.6666667
52:	H	0	3	0	3	6	0.20000	2.0000000
53:	T	1	1	3	3	7	0.23333	2.3333333
54:	T	1	1	0	0	1	0.03333	0.3333333
55:	T	1	0	1	0	1	0.03333	0.3333333
56:	T	1	1	3	3	7	0.23333	2.3333333
57:	H	0	1	3	3	7	0.23333	2.3333333
58:	H	0	0	0	3	3	0.10000	1.0000000
59:	T	1	0	3	1	4	0.13333	1.3333333
60:	T	1	0	3	0	3	0.10000	1.0000000
61:	T	1	1	1	1	3	0.10000	1.0000000
62:	H	0	1	1	3	5	0.16667	1.6666667
63:	H	0	3	0	3	6	0.20000	2.0000000

```
64:         H    0      3      3      1           7  0.23333      2.3333333
65:         H    0      3      3      3           9  0.30000      3.0000000
66:         H    0      0      1      1           2  0.06667      0.6666667
67:         H    0      0      1      0           1  0.03333      0.3333333
68:         H    0      3      1      0           4  0.13333      1.3333333
69:         H    0      0      0      0           0  0.00000      0.0000000
70:         T    1      3      3      0           6  0.20000      2.0000000
71:         T    1      0      3      3           6  0.20000      2.0000000
72:         T    1      3      3      3           9  0.30000      3.0000000
    head_tail test throw1 throw2 throw3 total_score accuracy mean_allthrows
```

```
model_reg <- lm(accuracy ~ test + frequency, data = dataset)
summary(model_reg)
```

```

Call:
lm(formula = accuracy ~ test + frequency, data = dataset)

Residuals:
      Min        1Q    Median        3Q       Max
-0.175318 -0.058090 -0.002984  0.051856  0.258012

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.156551   0.020827   7.517 1.65e-10 ***
test         0.018767   0.023787   0.789    0.433
frequency1   0.006156   0.024693   0.249    0.804
frequency2  -0.025901   0.041114  -0.630    0.531
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.09579 on 68 degrees of freedom
Multiple R-squared:  0.02504,   Adjusted R-squared:  -0.01798
F-statistic: 0.582 on 3 and 68 DF,  p-value: 0.6288
```

```
model_reg <- lm(accuracy ~ test + frequency + Gender + Degree , data = dataset)
summary(model_reg)
```

```

Call:
lm(formula = accuracy ~ test + frequency + Gender + Degree, data = dataset)

Residuals:
      Min        1Q    Median        3Q       Max
-0.188973 -0.064184 -0.001149  0.051239  0.277812
```

```
Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.1422762  0.0256387   5.549 5.88e-07 ***
test             0.0132414  0.0240538   0.550    0.584
frequency1      -0.0064747  0.0259003  -0.250    0.803
frequency2      -0.0319734  0.0434511  -0.736    0.465
GenderM          0.0330484  0.0250365   1.320    0.192
DegreeOthers     0.0467808  0.0479029   0.977    0.332
DegreePHD        0.1509572  0.1000999   1.508    0.136
DegreeUnderGrad  0.0004066  0.0265816   0.015    0.988
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.09587 on 64 degrees of freedom
Multiple R-squared:  0.08097,   Adjusted R-squared:  -0.01955
F-statistic: 0.8055 on 7 and 64 DF,  p-value: 0.5858
```

COHEN_D

I can see from the output of the t-test that the p-value is 0.2853,

which is greater than the commonly used alpha level of 0.05.

This means that we fail to reject the null hypothesis that

the mean accuracy between the treatment and control groups is equal.

```
group1 <- data_treatment$accuracy
group2 <- data_control$accuracy

d <- cohen.d(group1,group2)
d
```

```
Cohen's d

d estimate: 0.2538481 (small)
95 percent confidence interval:
     lower      upper
-0.2181347  0.7258309
```

Therefore, we conducted the power test with 36 participants in each group

with previously calculated Cohen's D value of d=0.2538481. The power of experiment was 0.1859243 and a significance level of 0.05 which is a significantly low power experiment.

```r
pwr.t.test(n=36, d=0.2538481, sig.level = 0.05, power=NULL, type = "two.sample")
```

```
     Two-sample t test power calculation

              n = 36
              d = 0.2538481
      sig.level = 0.05
          power = 0.1859243
    alternative = two.sided

NOTE: n is number in *each* group
```

Further, we conducted a second power test to determine how many observation we require to achieve a power of 0.8 for the experiment. According to the test results, we require 245 participants in each group to achieve a power of 0.8.

```r
pwr.t.test(n=NULL, d=0.2538481, sig.level = 0.05, power=0.8, type = "two.sample")
```

```
     Two-sample t test power calculation

              n = 244.5705
              d = 0.2538481
      sig.level = 0.05
          power = 0.8
    alternative = two.sided

NOTE: n is number in *each* group
```

Since the p-value is greater than the significance level of 0.05, we fail to reject the null hypothesis.

This means that we do not have sufficient evidence to conclude that the true proportion is different from 0.5.

The 95 % CI for the true proportion is (0.3874709, 0.6125291).

This means that we can be 95 percent confident that the true proportion falls within this interval.

The sample estimate of the proportion is 0.5, which is exactly the null hypothesis value.

Hence, the randomization was done properly.

```r
#Randomization Check
prop.test(dataset[test == 1, .N], 72, 0.5)
```

```
    1-sample proportions test without continuity correction

data:  dataset[test == 1, .N] out of 72, null probability 0.5
X-squared = 0, df = 1, p-value = 1
alternative hypothesis: true p is not equal to 0.5
95 percent confidence interval:
 0.3874709 0.6125291
sample estimates:
  p
0.5
```