AudioProj Report

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The Relationship between Speech Acoustics and Gender

Our Hypothesis: Sounds where $f_1 - f_0$ or f_1/f_0 are larger are more likely to come from female speakers.

R Packages/ Libraries

```
library(caret)
library(tidyverse)
library(factoextra)
library(cluster)
library(ggplot2)
library(e1071)
library(tidyr)
library(skimr)
library(readxl)
library(kernlab)
library(randomForest)
```

Set working directory for R Studio

```
wd <- getwd() %>% str_replace("/scripts/R/praat_processing$", "")
setwd(wd)
getwd()
```

```
## [1] "C:/r/Ai-Yukino/smol-puhe"
```

```
rm(wd)

data <- read_csv("./data/filtered_data.csv")
```

```
## New names:
## Rows: 8564 Columns: 19
## -- Column specification
## -------------------------------------------------------- Delimiter: "," dbl
## (19): ...1, time, f1, b1, f2, b2, f3, b3, f4, b4, f1p, f2p, f3p, f4p, f0...
## i Use `spec()` to retrieve the full column specification for this data. i
## Specify the column types or set `show_col_types = FALSE` to quiet this message.
## * `` -> `...1`
```

```
spec(data)
```

```
## cols(
##   ...1 = col_double(),
```

```
##   time = col_double(),
##   f1 = col_double(),
##   b1 = col_double(),
##   f2 = col_double(),
##   b2 = col_double(),
##   f3 = col_double(),
##   b3 = col_double(),
##   f4 = col_double(),
##   b4 = col_double(),
##   f1p = col_double(),
##   f2p = col_double(),
##   f3p = col_double(),
##   f4p = col_double(),
##   f0 = col_double(),
##   intensity = col_double(),
##   harmonicity = col_double(),
##   age = col_double(),
##   gender = col_double()
## )
```

Supervised Model: Caret Prediction

```
data<- read_excel("./data/filtered_data.xls")
```

```
## New names:
## * `` -> `...1`
```

```
dim(data)
```

```
## [1] 8564   19
```

```
df <- data[c("f1", "f2", "f3", "f4", "f0", "intensity", "harmonicity", "age","gender")]
head(df)
```

```
## # A tibble: 6 x 9
##      f1    f2    f3    f4    f0 intensity harmonicity   age gender
##   <dbl> <dbl> <dbl> <dbl> <dbl>     <dbl>       <dbl> <dbl>  <dbl>
## 1  660. 2377. 2909. 4177.  232.      62.4      -215.     30      0
## 2  504. 2379. 2880. 4184.  232.      65.3      -213.     30      0
## 3  405  2391. 2912. 4198.  231.      69        -200      30      0
## 4  388. 2440. 3053. 4205.  231.      72.5      -168.     30      0
## 5  438. 2497. 3150. 4159.  230.      75.5      -121      30      0
## 6  478. 2539. 3191. 4070.  230.      78.1       -68.8    30      0
```

```
# dimensions of data
dim(df)
```

```
## [1] 8564    9
```

```
#create output as target class
df$gender = as.factor(df$gender)

# Step 1: Get row numbers for the training data
trainRowNumbers <- createDataPartition(df$gender, p=0.8, list=FALSE)

# Step 2: Create the training  data
trainData <- df[trainRowNumbers,]
```

```
# Step 3: Create the test data
testData <- df[-trainRowNumbers,]

# Store X and Y for later use.
x = trainData[ 1:5]
y = factor(trainData[[9]])


# Sys.setlocale( locale = 'Chinese')
Sys.setlocale('LC_ALL','C')
```

```
## [1] "C"
```

```
#skimmed <- skim_to_wide(trainData)
#skimmed[,]
skim(df)
```

Table 1: Data summary

Name	df
Number of rows	8564
Number of columns	9
Column type frequency:	
factor	1
numeric	8
Group variables	None

Variable type: factor

skim_variable	n_missing	complete_rate	ordered	n_unique	top_counts
gender	0	1	FALSE	2	0: 5028, 1: 3536

Variable type: numeric

skim_variable	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
f1	0	1	491.50	160.96	54.2	376.78	471.70	600.45	1459.3	
f2	0	1	1307.65	463.87	306.1	984.80	1202.65	1595.00	3068.8	
f3	0	1	2141.14	487.10	912.8	1757.47	2133.65	2537.83	4252.8	
f4	0	1	3112.38	541.52	1677.6	2750.18	3030.15	3381.98	5480.9	
f0	0	1	159.94	52.27	65.7	115.68	159.30	203.40	301.9	
intensity	0	1	72.74	7.17	51.7	67.50	73.45	78.80	85.9	
harmonicity	0	1	-19.83	73.06	-226.2	3.90	9.90	15.00	50.3	
age	0	1	23.99	6.43	20.0	20.00	20.00	30.00	40.0	

```
df %>% dplyr::group_by(gender) %>% skim()
```

Table 4: Data summary

Name	Piped data
Number of rows	8564
Number of columns	9
Column type frequency:	
numeric	8
Group variables	gender

Variable type: numeric

skim_variable	gender	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
f1	0	0	1	495.56	177.38	54.2	366.58	476.75	621.00	1459.3	
f1	1	0	1	485.71	134.03	91.3	385.58	464.45	574.92	1247.5	
f2	0	0	1	1348.04	535.39	306.1	950.08	1241.60	1683.03	3068.8	
f2	1	0	1	1250.23	328.62	392.5	1035.62	1183.50	1478.85	2313.9	
f3	0	0	1	2231.84	535.51	912.8	1778.60	2276.35	2692.80	4252.8	
f3	1	0	1	2012.18	372.29	940.4	1738.47	2059.35	2299.75	3349.7	
f4	0	0	1	3243.46	587.43	1689.7	2809.07	3068.50	3676.60	5480.9	
f4	1	0	1	2925.99	400.52	1677.6	2653.32	2983.65	3211.02	4222.8	
f0	0	0	1	189.75	41.83	86.1	159.80	199.00	216.80	301.9	
f0	1	0	1	117.56	32.71	65.7	90.20	105.80	137.90	266.9	
intensity	0	0	1	72.84	7.06	52.5	68.10	73.40	78.60	85.9	
intensity	1	0	1	72.59	7.33	51.7	66.70	73.50	79.00	83.8	
harmonicity	0	0	1	-20.76	75.00	-226.2	4.00	10.90	16.00	34.9	
harmonicity	1	0	1	-18.50	70.20	-225.8	3.70	8.50	13.00	50.3	
age	0	0	1	25.92	7.33	20.0	20.00	20.00	30.00	40.0	
age	1	0	1	21.24	3.30	20.0	20.00	20.00	20.00	30.0	

```
#create a list of 80% of rows for training
validation_index <- createDataPartition(df$gender, p=0.80, list=FALSE)
validation <- df[-validation_index,]
df <- df[validation_index,]


# dimensions of data
dim(df)
```

```
## [1] 6852    9
```

```
#summarize attribute distributions
summary(df)
```

```
##        f1              f2              f3              f4
##  Min.   :  58.9   Min.   : 306.1   Min.   : 912.8   Min.   :1678
##  1st Qu.: 376.1   1st Qu.: 985.5   1st Qu.:1760.8   1st Qu.:2751
##  Median : 471.3   Median :1202.5   Median :2138.4   Median :3028
##  Mean   : 490.9   Mean   :1309.9   Mean   :2142.7   Mean   :3114
##  3rd Qu.: 599.4   3rd Qu.:1597.3   3rd Qu.:2536.1   3rd Qu.:3384
```

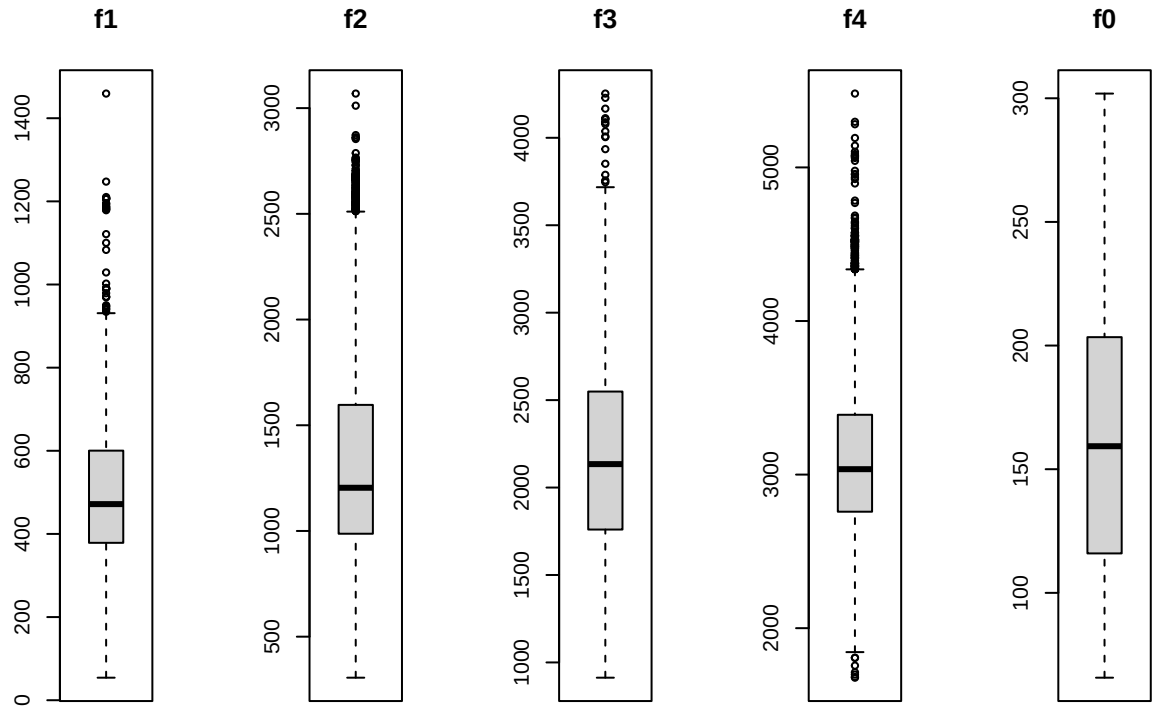
```
##  Max.   :1459.3   Max.   :3068.8   Max.   :4252.8   Max.   :5481
##        f0          intensity      harmonicity          age        gender
##  Min.   : 66.0   Min.   :51.70   Min.   :-226.20   Min.   :20.00   0:4023
##  1st Qu.:115.7   1st Qu.:67.50   1st Qu.:   3.90   1st Qu.:20.00   1:2829
##  Median :159.2   Median :73.40   Median :   9.80   Median :20.00
##  Mean   :159.9   Mean   :72.72   Mean   : -19.81   Mean   :24.01
##  3rd Qu.:203.5   3rd Qu.:78.80   3rd Qu.:  15.00   3rd Qu.:30.00
##  Max.   :301.9   Max.   :85.90   Max.   :  50.30   Max.   :40.00
```

```
#summarize the class distribution
percentage <-prop.table(table(df$gender)) *100
y = factor(trainData[[9]])
cbind(freq=table(df$gender), percentage =percentage)
```

```
##   freq percentage
## 0 4023   58.71278
## 1 2829   41.28722
```

```
#split input and output
#x<-df[,1:5]
#y<-as.factor(df[[9]])

#boxplot for each attribute
par(mfrow=c(1,5))
  for(i in 1:5){
    boxplot(x[,i], main=names(df)[i])
  }
```



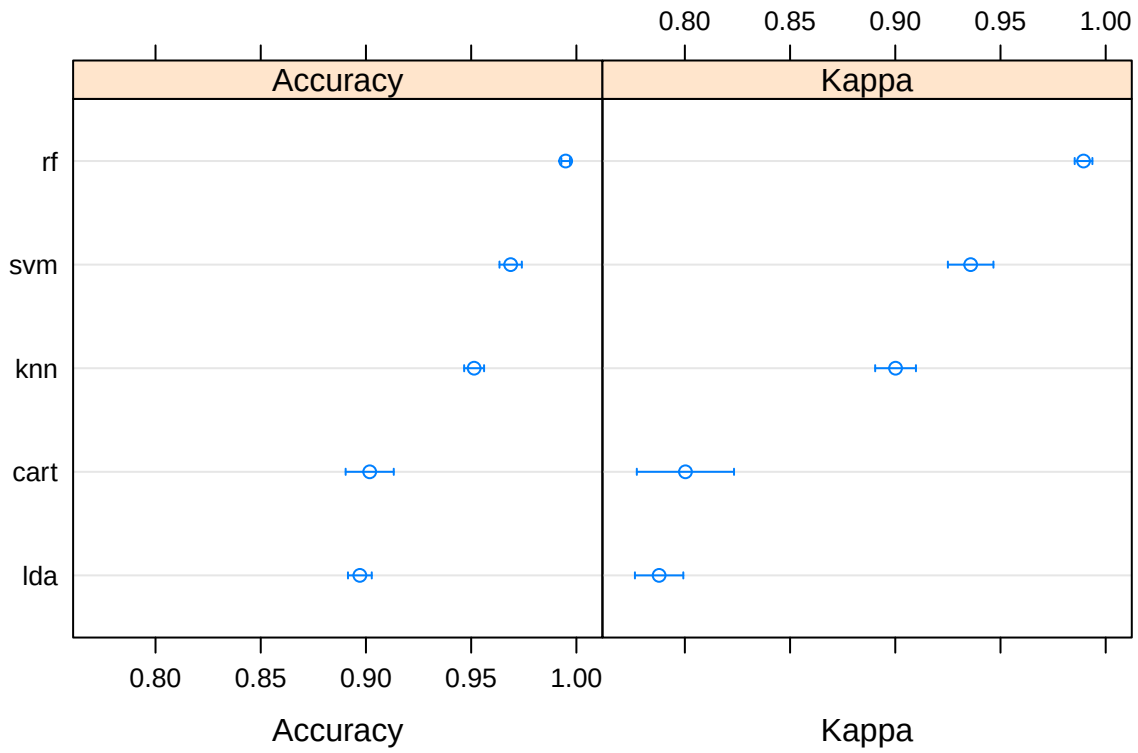
```r
# Run algorithms using 10-fold cross validation
control <- trainControl(method="cv", number=10)
metric <- "Accuracy"

# a) linear algorithms
set.seed(7)
fit.lda <- train(gender~., data=df, method="lda", metric=metric, trControl=control)
# b) nonlinear algorithms
# CART
set.seed(7)
fit.cart <- train(gender~., data=df, method="rpart", metric=metric, trControl=control)
# kNN
set.seed(7)
fit.knn <- train(gender~., data=df, method="knn", metric=metric, trControl=control)
# c) advanced algorithms
# SVM
set.seed(7)
fit.svm <- train(gender~., data=df, method="svmRadial", metric=metric, trControl=control)
# Random Forest
set.seed(7)
fit.rf <- train(gender~., data=df, method="rf", metric=metric, trControl=control)

#summarize accuracy of models
results <- resamples(list(lda=fit.lda, cart=fit.cart, knn=fit.knn, svm=fit.svm, rf=fit.rf))
summary(results)
```

```
##
## Call:
## summary.resamples(object = results)
##
## Models: lda, cart, knn, svm, rf
## Number of resamples: 10
##
## Accuracy
##           Min.   1st Qu.    Median      Mean   3rd Qu.      Max. NA's
## lda  0.8859649 0.8912409 0.8971558 0.8971068 0.9025915 0.9081633    0
## cart 0.8715328 0.8922562 0.9051808 0.9017826 0.9145985 0.9197080    0
## knn  0.9430657 0.9463695 0.9518248 0.9514037 0.9561755 0.9620438    0
## svm  0.9562044 0.9635451 0.9700730 0.9687670 0.9730321 0.9810219    0
## rf   0.9897959 0.9930715 0.9941606 0.9948924 0.9970803 0.9985423    0
##
## Kappa
##           Min.   1st Qu.    Median      Mean   3rd Qu.      Max. NA's
## lda  0.7654321 0.7758301 0.7871419 0.7877736 0.7988673 0.8110259    0
## cart 0.7402329 0.7794541 0.8079552 0.8002719 0.8252169 0.8360481    0
## knn  0.8827719 0.8900090 0.9008069 0.9001303 0.9097673 0.9221325    0
## svm  0.9104325 0.9250667 0.9384616 0.9358247 0.9445210 0.9608831    0
## rf   0.9789808 0.9856992 0.9879640 0.9894685 0.9939836 0.9969941    0
```

```r
# compare accuracy of models
dotplot(results)
```



Confidence Level: 0.95

```
# best model is random forest
print(fit.rf)
```

```
## Random Forest
##
## 6852 samples
##    8 predictor
##    2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 6167, 6166, 6166, 6167, 6166, 6167, ...
## Resampling results across tuning parameters:
##
##   mtry  Accuracy   Kappa
##   2     0.9948924  0.9894685
##   5     0.9918274  0.9831368
##   8     0.9897836  0.9789223
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was mtry = 2.
```

```
#analyze results in confusion matrix

# estimate skill of rf on the validation data
predictions <- predict(fit.rf, validation)
confusionMatrix(predictions, validation$gender)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    0    1
##          0 1002    3
##          1    3  704
##
##                Accuracy : 0.9965
##                  95% CI : (0.9924, 0.9987)
##     No Information Rate : 0.587
##     P-Value [Acc > NIR] : <2e-16
##
##                   Kappa : 0.9928
##
##  Mcnemar's Test P-Value : 1
##
##             Sensitivity : 0.9970
##             Specificity : 0.9958
##          Pos Pred Value : 0.9970
##          Neg Pred Value : 0.9958
##              Prevalence : 0.5870
##          Detection Rate : 0.5853
##    Detection Prevalence : 0.5870
##       Balanced Accuracy : 0.9964
##
##        'Positive' Class : 0
##
```

Supervised Learning: Classification

```
# Selecting specific columns
data <- data[, c('f0', 'f1', 'f2', 'gender')]
head(data)
```

```
## # A tibble: 6 x 4
##      f0    f1    f2 gender
##   <dbl> <dbl> <dbl>  <dbl>
## 1  232.  660. 2377.      0
## 2  232.  504. 2379.      0
## 3  231.  405  2391.      0
## 4  231.  388. 2440.      0
## 5  230.  438. 2497.      0
## 6  230.  478. 2539.      0
```

```
# Splitting data

library(caTools)

sample.split(data$gender,SplitRatio = 0.65)->split_values
subset(data,split_values==T)->train_set
subset(data,split_values==F)->test_set

# Loading RPART to build classification model
library(rpart)
```

```
rpart(gender ~ ., data = train_set)->mod_class
predict(mod_class, test_set, type = "matrix" )->result_class
table(test_set$gender, result_class)
```

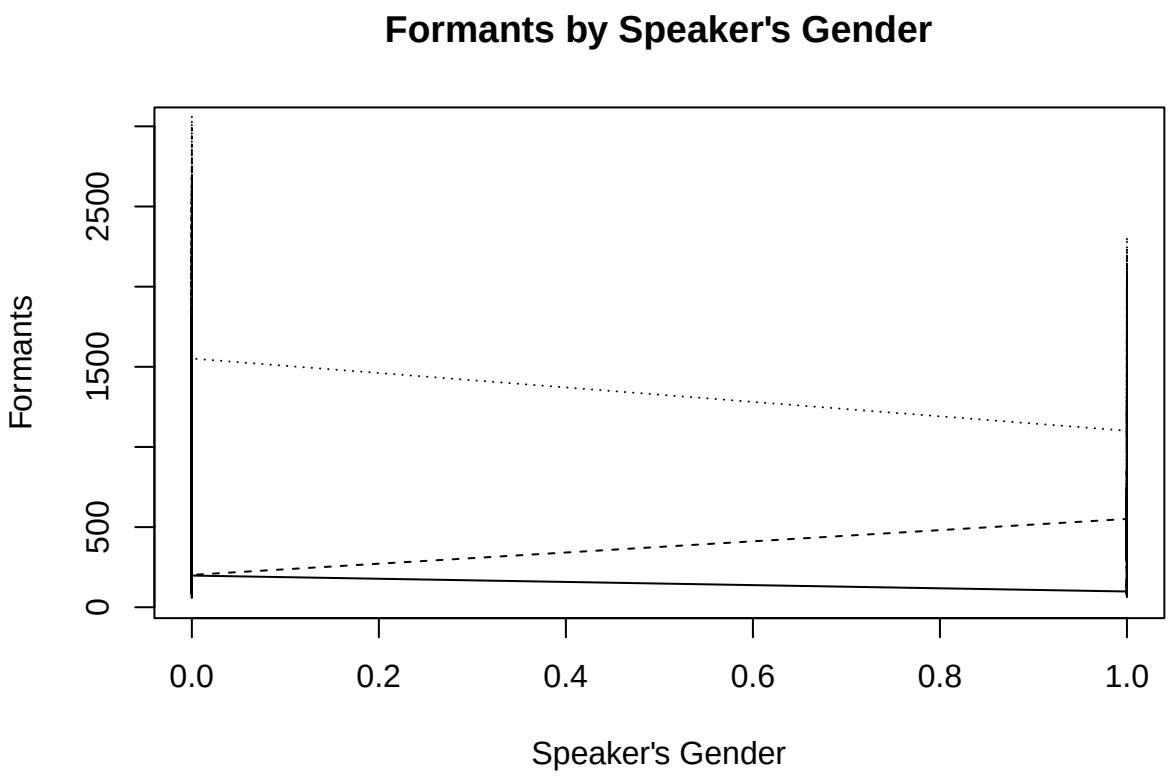
```
##    result_class
##     0.0411985018726592 0.0431323283082077 0.114285714285714 0.369369369369369
##   0                134                1241                48                83
##   1                  9                  73                12                49
##    result_class
##     0.650602409638554 0.727355072463768 0.902349486049927
##   0                19                170                65
##   1                26                434               635
```

```
library(ggplot2)

data <- read_csv("./data/filtered_data.csv")
```

```
## New names:
## Rows: 8564 Columns: 19
## -- Column specification
## -------------------------------------------------------- Delimiter: "," dbl
## (19): ...1, time, f1, b1, f2, b2, f3, b3, f4, b4, f1p, f2p, f3p, f4p, f0...
## i Use `spec()` to retrieve the full column specification for this data. i
## Specify the column types or set `show_col_types = FALSE` to quiet this message.
## * `` -> `...1`
```

```
plot(data$gender, data$f0,
     main = "Formants by Speaker's Gender",
     xlab = "Speaker's Gender",
     ylab = "Formants",
     type = "l",
     ylim = c(50, 3000))
lines(data$gender, data$f1,
      lty = "dashed")
lines(data$gender, data$f2,
      lty = "dotted")
```



Unsupervised Learning: Principal Components Analysis

```
data <- data[, c('f0', 'f1', 'f2', 'gender')]

#Calculate the Principal Components
results <- prcomp(data, scale = TRUE)

#reverse the signs
results$rotation <- -1*results$rotation

#display principal components
results$rotation
```

```
##                PC1         PC2         PC3        PC4
## f0      0.69431289 -0.14718505  0.07206468 0.70076591
## f1      0.04984055  0.70981372  0.70208544 0.02750343
## f2      0.13751357  0.68771333 -0.70821956 0.08102747
## gender -0.70465279  0.03938812 -0.01754345 0.70824096
```

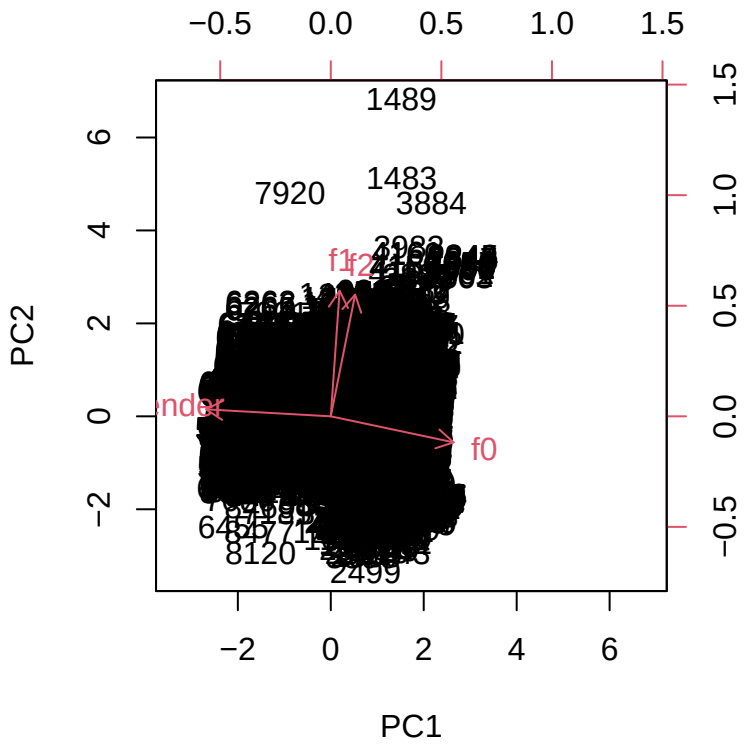
```
#reverse the signs of the scores
results$x <- -1*results$x

#display the first six scores
head(results$x)
```

```
##           PC1       PC2        PC3       PC4
## [1,] 1.920106 2.0947255 -0.7817518 0.5905168
```

```
## [2,] 1.865724 1.4107358 -1.4663625 0.5574911
## [3,] 1.831773 0.9911598 -1.9184719 0.5358478
## [4,] 1.834400 0.9917099 -2.0651772 0.5347974
## [5,] 1.860228 1.2985551 -1.9352620 0.5466468
## [6,] 1.876848 1.5356663 -1.8286434 0.5526373
```

```
biplot(results, scale = 0)
```

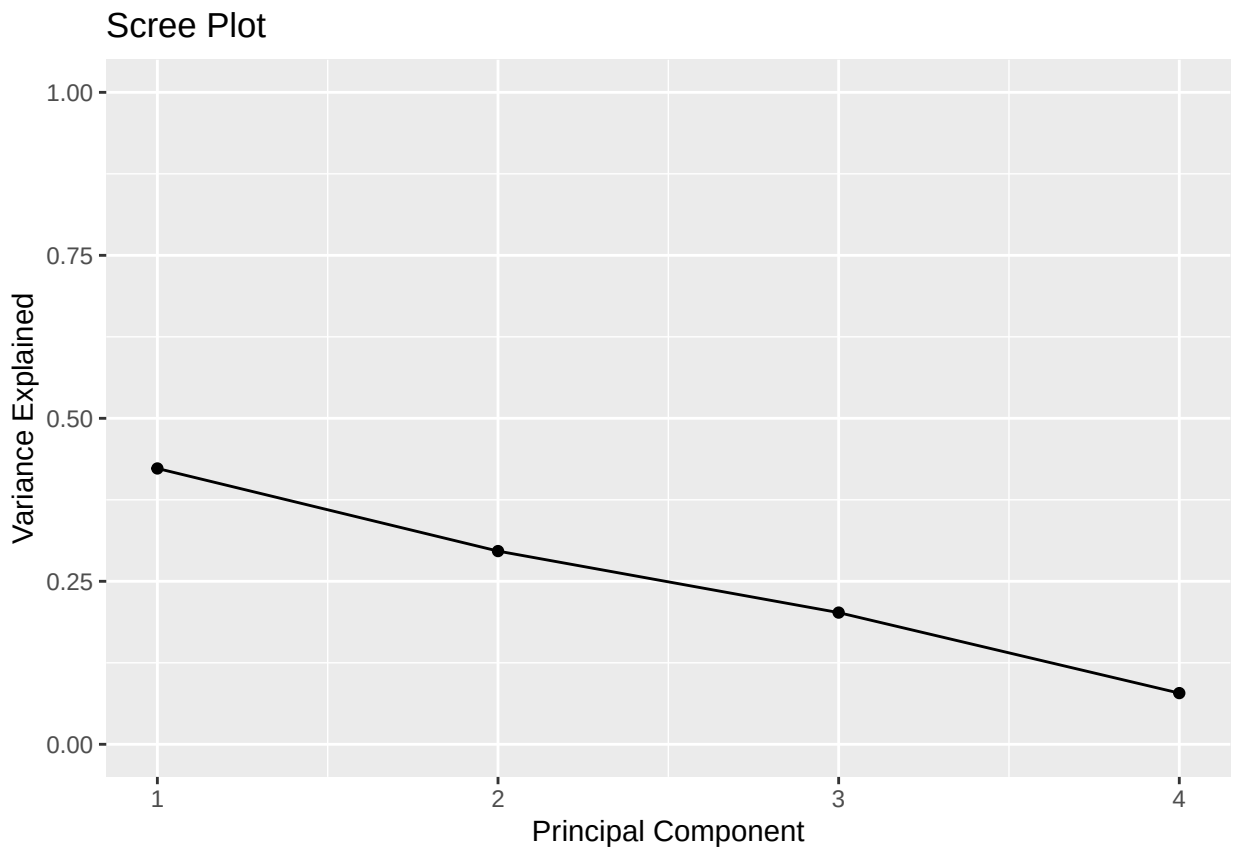



```
#calculate total variance explained by each principal component
results$sdev^2 / sum(results$sdev^2)
```

```
## [1] 0.42310653 0.29636698 0.20199740 0.07852909
```

```
#calculate total variance explained by each principal component
var_explained = results$sdev^2 / sum(results$sdev^2)

#create scree plot
qplot(c(1:4), var_explained) +
  geom_line() +
  xlab("Principal Component") +
  ylab("Variance Explained") +
  ggtitle("Scree Plot") +
  ylim(0, 1)
```



Kmeans()

```
data <- read_csv("./data/filtered_data.csv")
```

```
## New names:
## Rows: 8564 Columns: 19
## -- Column specification
## -------------------------------------------------------- Delimiter: "," dbl
## (19): ...1, time, f1, b1, f2, b2, f3, b3, f4, b4, f1p, f2p, f3p, f4p, f0...
## i Use `spec()` to retrieve the full column specification for this data. i
## Specify the column types or set `show_col_types = FALSE` to quiet this message.
## * `` -> `...1`
```

```
data$difference = data$f1 - data$f0
data$quotient = data$f1/data$f0
dataMod = subset(data, select = -c(b1,b2,b3,b4,f1p,f2p,f3p,f4p, intensity, harmonicity, ...1, time))

model1 = lm(difference~gender, data = data)
summary(model1)
```

```
##
## Call:
## lm(formula = difference ~ gender, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
```

```
## -450.31 -113.88  -16.36  113.09  985.39
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  305.813      2.360  129.56   <2e-16 ***
## gender        62.344      3.673   16.97   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 167.4 on 8562 degrees of freedom
## Multiple R-squared:  0.03255,    Adjusted R-squared:  0.03244
## F-statistic: 288.1 on 1 and 8562 DF,  p-value: < 2.2e-16
```

```
model2 = lm(quotient~gender, data = data)
summary(model2)
```

```
##
## Call:
## lm(formula = quotient ~ gender, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.6579 -1.0880 -0.2212  0.7798  7.5781
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.81051    0.02086  134.73   <2e-16 ***
## gender       1.58823    0.03246   48.92   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.479 on 8562 degrees of freedom
## Multiple R-squared:  0.2185, Adjusted R-squared:  0.2184
## F-statistic:  2393 on 1 and 8562 DF,  p-value: < 2.2e-16
```

```
model3 = lm(difference~., data = subset(dataMod, select = -c(quotient, f0, f1)))
summary(model3)
```

```
##
## Call:
## lm(formula = difference ~ ., data = subset(dataMod, select = -c(quotient,
##     f0, f1)))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -425.60 -114.10  -27.02  116.59  750.07
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 36.558748  12.059524   3.032  0.00244 **
## f2           0.047345   0.004416  10.722  < 2e-16 ***
## f3          -0.051975   0.005376  -9.669  < 2e-16 ***
## f4           0.104182   0.004649  22.411  < 2e-16 ***
## age         -0.635777   0.302496  -2.102  0.03560 *
## gender      85.659570   3.827000  22.383  < 2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 159.4 on 8558 degrees of freedom
## Multiple R-squared:  0.123,  Adjusted R-squared:  0.1225
## F-statistic:   240 on 5 and 8558 DF,  p-value: < 2.2e-16
```

```
model4 = lm(quotient~., data = subset(dataMod, select = -c(difference, f0, f1)))
summary(model4)
```

```
##
## Call:
## lm(formula = quotient ~ ., data = subset(dataMod, select = -c(difference,
##     f0, f1)))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.4224 -1.0257 -0.2756  0.6833  8.0709
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.137e+00  1.082e-01  10.509  < 2e-16 ***
## f2           2.053e-04  3.963e-05   5.182 2.25e-07 ***
## f3          -3.664e-04  4.824e-05  -7.596 3.39e-14 ***
## f4           8.423e-04  4.172e-05  20.191  < 2e-16 ***
## age         -1.998e-02  2.715e-03  -7.361 2.00e-13 ***
## gender       1.702e+00  3.434e-02  49.552  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.43 on 8558 degrees of freedom
## Multiple R-squared:  0.2696, Adjusted R-squared:  0.2691
## F-statistic: 631.6 on 5 and 8558 DF,  p-value: < 2.2e-16
```

```
# fviz_nbclust(dataMod, kmeans, method = "wss")
# gapStat = clusGap(dataMod, FUN = kmeans, K.max = 10, B = 50)
# fviz_gap_stat(gapStat)

km1 = kmeans(dataMod, centers = 2)
km1
```

```
## K-means clustering with 2 clusters of sizes 5471, 3093
##
## Cluster means:
##         f1       f2       f3       f4       f0      age    gender difference
## 1 464.7688 1105.363 1867.705 2817.508 158.3700 22.55346 0.4946079   306.3988
## 2 538.7707 1665.471 2624.814 3633.948 162.7198 26.53088 0.2683479   376.0509
##   quotient
## 1 3.383596
## 2 3.612509
##
## Clustering vector:
##    [1] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [38] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
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##
## Within cluster sum of squares by cluster:
## [1] 1967808845 1820956419
##  (between_SS / total_SS =  44.9 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
km2 = kmeans(dataMod, centers = 6)
km2
```

```
## K-means clustering with 6 clusters of sizes 2057, 644, 1492, 2728, 1059, 584
##
## Cluster means:
##         f1       f2       f3       f4       f0      age     gender difference
## 1 500.3795 1021.104 2139.334 3083.097 149.1233 22.42100 0.55517744   351.2562
## 2 518.6556 2324.435 2858.790 4146.793 162.5298 28.50932 0.03105590   356.1258
## 3 470.5379 1635.535 2202.641 2956.911 166.4438 25.54290 0.49463807   304.0941
## 4 439.6321 1018.949 1625.304 2642.912 158.7868 21.65689 0.47140762   280.8452
## 5 589.9122 1669.478 2616.198 3455.871 164.9452 25.17469 0.30972616   424.9669
## 6 547.5981 1050.525 2747.208 4042.085 174.8921 29.31507 0.03767123   372.7060
##   quotient
## 1 3.903111
## 2 3.341180
## 3 3.094445
## 4 3.223908
## 5 3.913894
## 6 3.335925
##
## Clustering vector:
##    [1] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
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##
## Within cluster sum of squares by cluster:
## [1] 489396217 164783423 282950427 666813613 238808434 120955622
##  (between_SS / total_SS =  71.5 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
km3 = kmeans(dataMod, centers = 8)
km3
```

```
## K-means clustering with 8 clusters of sizes 1453, 900, 635, 946, 1201, 1428, 1454, 547
##
## Cluster means:
##         f1        f2       f3       f4       f0      age     gender difference
## 1 336.5734  903.2584 1846.489 2696.816 179.8498 22.40193 0.28836889   156.7235
## 2 492.0880 1098.2560 1516.196 2378.281 126.4786 21.10000 0.67444444   365.6094
## 3 517.5850 2329.7980 2860.110 4148.987 162.3616 28.51969 0.03149606   355.2235
## 4 597.4283 1695.4075 2629.808 3488.359 163.5754 25.22199 0.29598309   433.8530
## 5 470.0684  997.2983 2364.936 3139.407 137.0474 23.28893 0.65278934   333.0210
## 6 465.0550 1654.0148 2240.023 2978.712 166.7440 25.68627 0.48949580   298.3109
## 7 583.3814 1151.7581 1680.161 3029.181 163.4765 21.44429 0.49037139   419.9048
## 8 560.3782 1060.7963 2748.214 4081.187 176.1258 29.45155 0.02559415   384.2525
##   quotient
## 1 2.130599
## 2 4.393733
## 3 3.336520
## 4 3.973946
## 5 3.968721
## 6 3.060235
## 7 3.964132
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##
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##
## Within cluster sum of squares by cluster:
## [1] 247264894 170637337 160139697 202092572 222636743 250181838 229890355
## [8] 104236761
##  (between_SS / total_SS =  76.9 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```
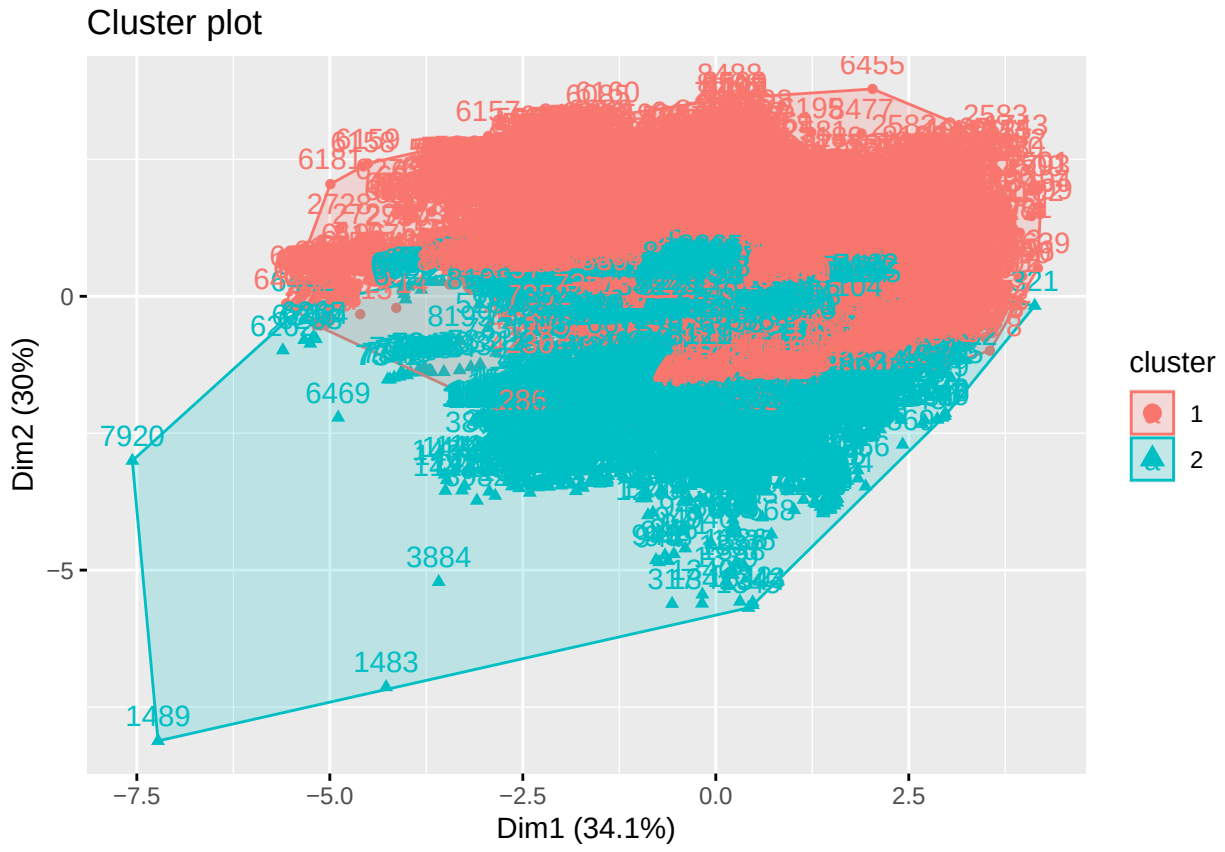
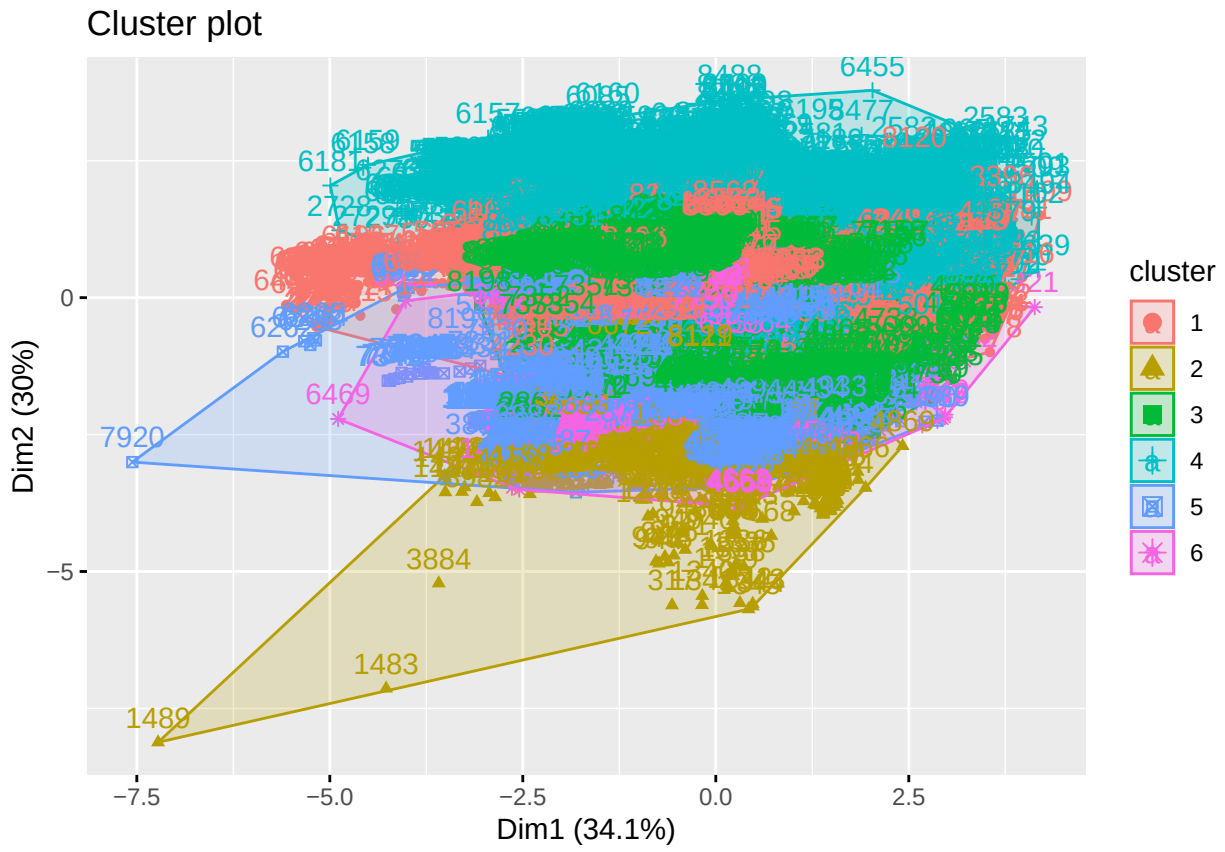

```
fviz_cluster(km1, dataMod)
```




```
fviz_cluster(km2, dataMod)
```

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fviz_cluster(km3, dataMod)
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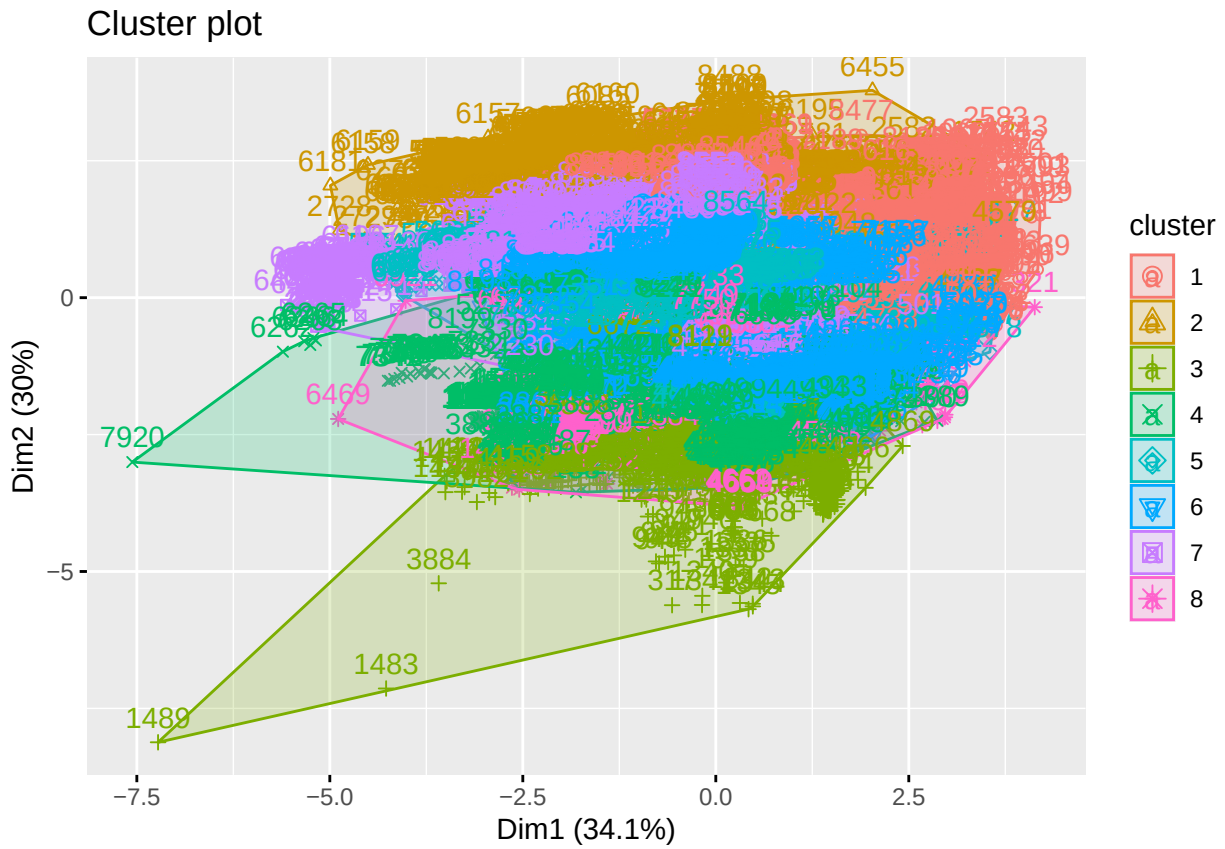


```
# fviz_nbclust(subset(dataMod, select = c(f1, f2, gender)), kmeans, method = "wss")
# gapStat2 = clusGap(subset(dataMod, select = c(f1, f2, gender)), FUN = kmeans, K.max = 10, B = 50)
# fviz_gap_stat(gapStat2)

km4 = kmeans(dataMod, centers = 2)
km4
```

```
## K-means clustering with 2 clusters of sizes 3093, 5471
##
## Cluster means:
##         f1       f2       f3       f4       f0      age    gender difference
## 1 538.7707 1665.471 2624.814 3633.948 162.7198 26.53088 0.2683479   376.0509
## 2 464.7688 1105.363 1867.705 2817.508 158.3700 22.55346 0.4946079   306.3988
##   quotient
## 1 3.612509
## 2 3.383596
##
## Clustering vector:
##    [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##   [38] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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##
## Within cluster sum of squares by cluster:
## [1] 1820956419 1967808845
##  (between_SS / total_SS =  44.9 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
km5 = kmeans(dataMod, centers = 4)
km5
```

```
## K-means clustering with 4 clusters of sizes 1232, 2767, 3687, 878
##
## Cluster means:
##         f1       f2       f3       f4       f0      age    gender difference
## 1 561.1452 1122.349 2635.124 3738.947 156.5554 27.16721 0.2719156   404.5898
## 2 511.9353 1505.775 2265.377 3063.705 160.3158 24.34767 0.5233104   351.6196
## 3 445.6362 1004.472 1718.053 2724.371 159.9216 21.84974 0.4567399   285.7146
## 4 521.9263 2216.447 2833.179 4015.921 163.5916 27.39180 0.0785877   358.3347
##   quotient
## 1 3.932533
## 2 3.625236
## 3 3.212660
## 4 3.376041
##
## Clustering vector:
##    [1] 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
##   [38] 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
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##
## Within cluster sum of squares by cluster:
## [1]  394566569  745333916 1033643338  272612267
##  (between_SS / total_SS =  64.4 %)
```

```
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
km6 = kmeans(dataMod, centers = 5)
km6
```

```
## K-means clustering with 5 clusters of sizes 1872, 793, 2168, 2788, 943
##
## Cluster means:
##         f1       f2       f3       f4       f0      age     gender difference
## 1 498.5663 1686.891 2320.866 3080.250 166.3780 25.20833 0.48076923   332.1882
## 2 519.2661 2253.776 2845.136 4057.906 164.4021 27.62926 0.05296343   354.8639
## 3 497.2595 1037.713 2134.855 3069.185 151.4563 22.47232 0.53228782   345.8032
## 4 439.6178 1031.743 1631.026 2641.932 158.0057 21.65710 0.47883788   281.6120
## 5 594.2322 1195.521 2714.999 3871.197 168.6391 28.89714 0.11134677   425.5931
##   quotient
## 1 3.292069
## 2 3.331443
## 3 3.815732
## 4 3.233213
## 5 3.811086
##
## Clustering vector:
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## [7919] 3 2 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
## [7956] 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3
## [7993] 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3
## [8030] 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
## [8067] 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
## [8104] 3 3 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 1 1 1 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 1
## [8141] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [8178] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 4 4 4 4 4 4 4 4 4 4 1 1
## [8215] 1 1 1 1 1 1 1 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 1 1 1 1 1 1 1 1 1 1
## [8252] 1 1 4 4 4 4 4 4 4 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 4 4 3 3 3 3 3 3
## [8289] 3 4 4 4 4 4 4 4 4 3 3 1 1 1 1 1 1 1 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [8326] 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [8363] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [8400] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 4 4 4 4 3 3 3 3 1 1 1 1 1 1 1 1 1
## [8437] 1 1 1 1 1 1 1 1 1 1 1 1 1 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
## [8474] 4 4 4 4 4 1 1 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3 3 3
## [8511] 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3
## [8548] 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3
##
## Within cluster sum of squares by cluster:
## [1] 413806923 226421743 522422768 695154353 260540375
##  (between_SS / total_SS =  69.2 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```
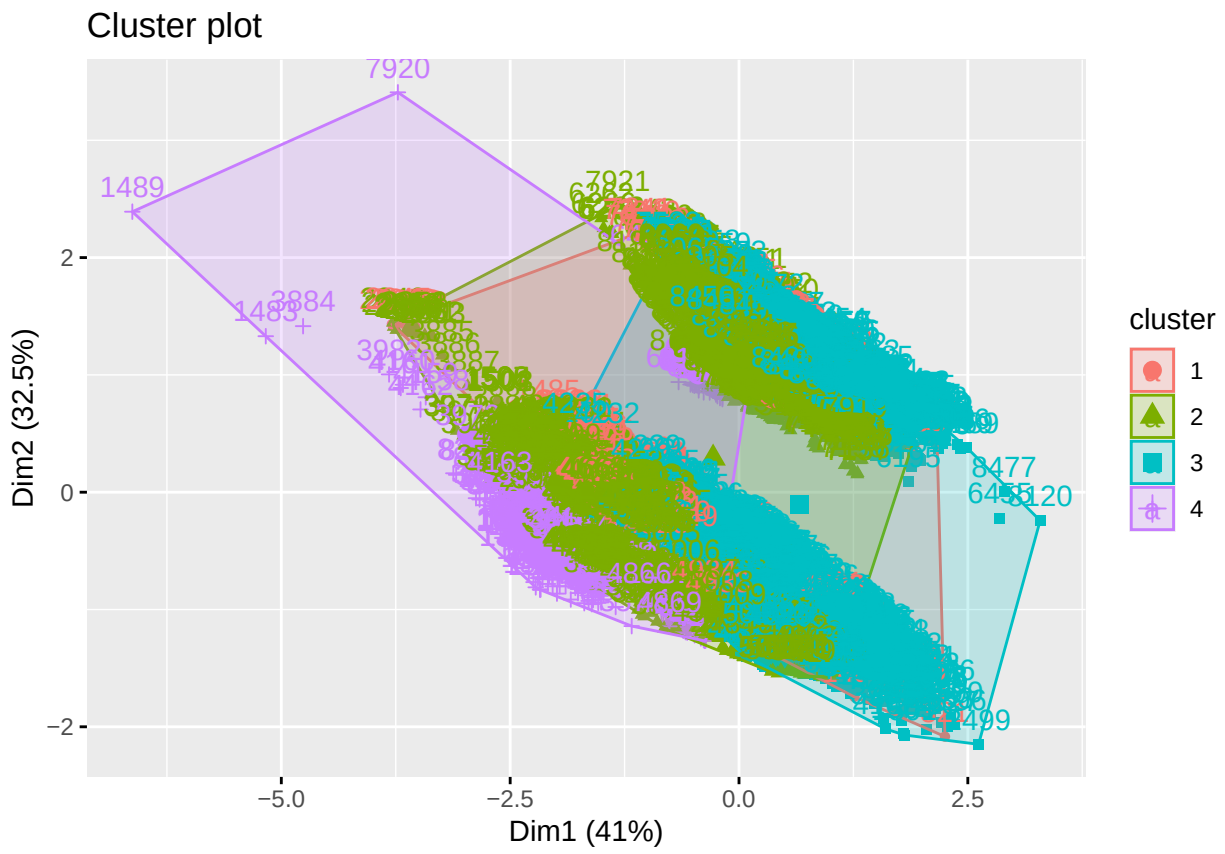
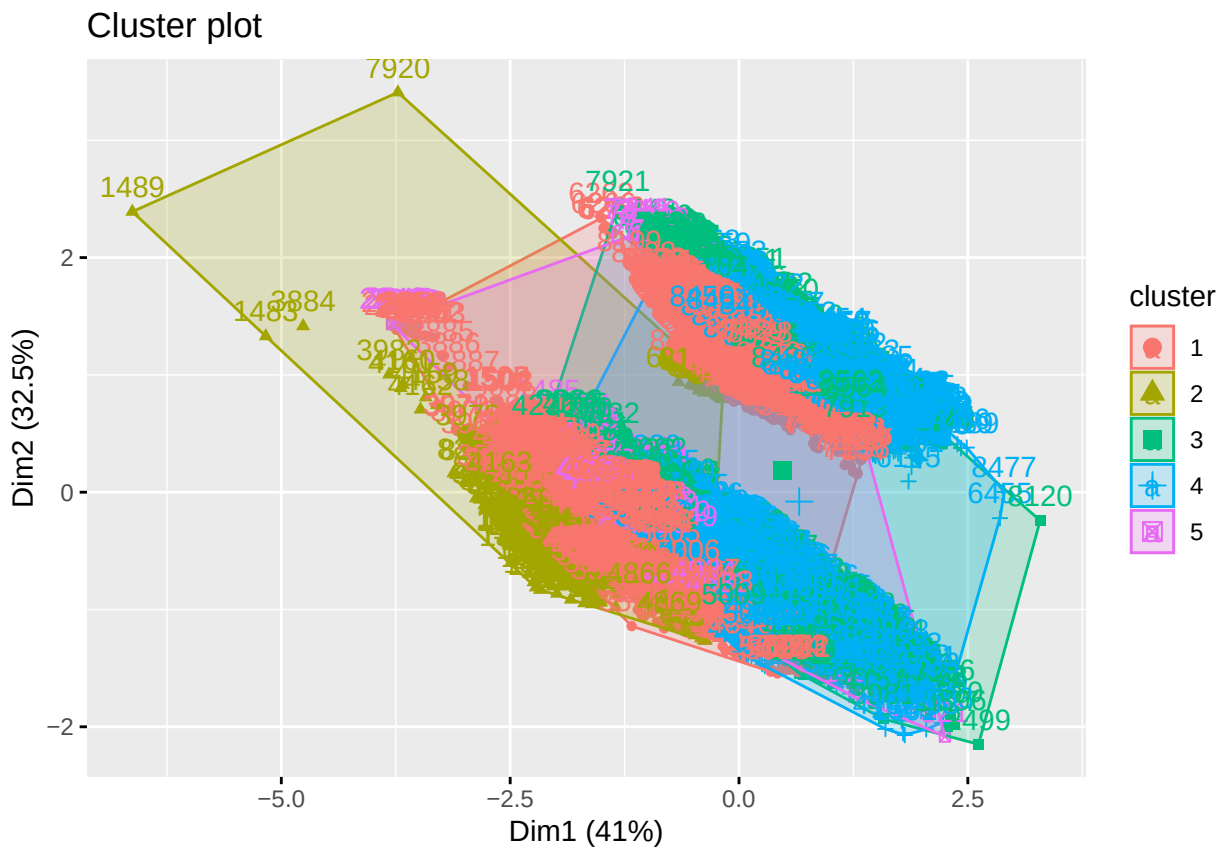

```
fviz_cluster(km4, subset(dataMod, select = c(f1, f2, gender)))
```

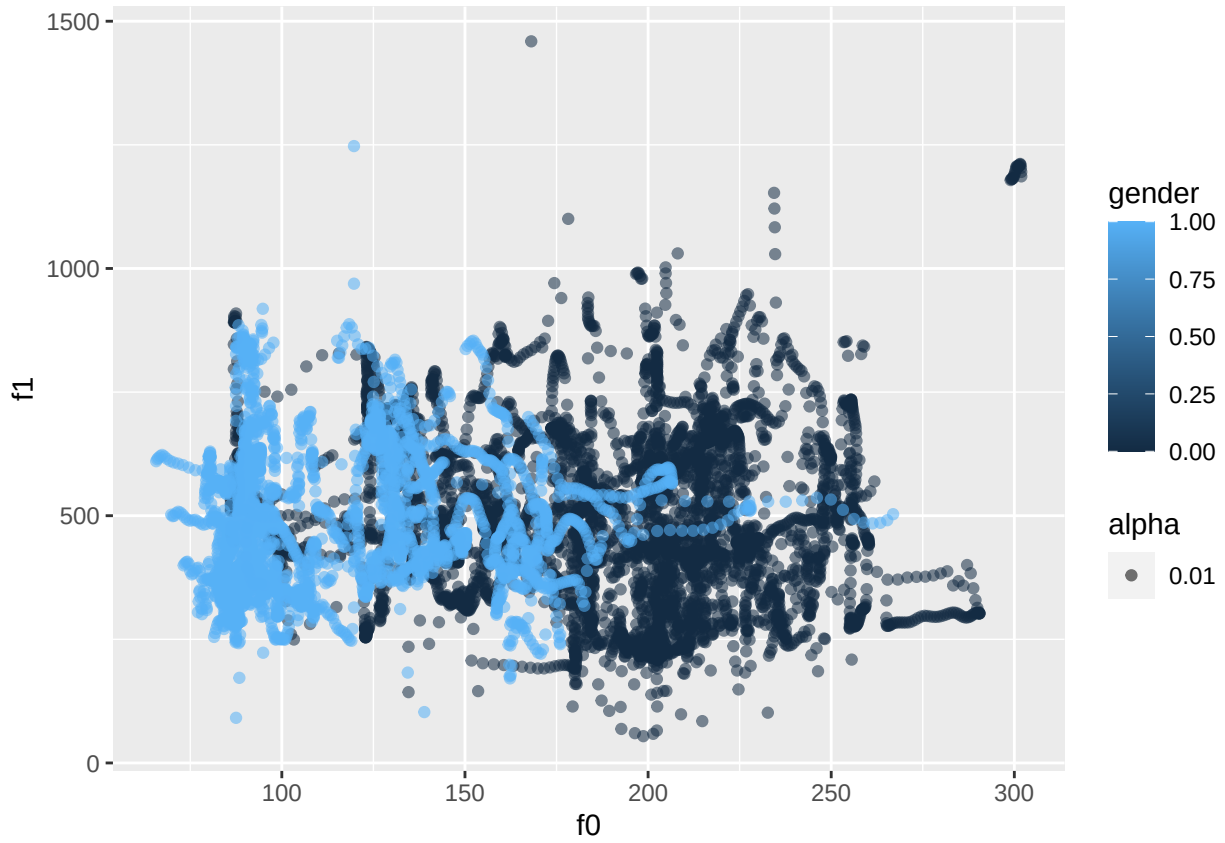

```
fviz_cluster(km5, subset(dataMod, select = c(f1, f2, gender)))
```




```
fviz_cluster(km6, subset(dataMod, select = c(f1, f2, gender)))
```




```
ggplot(dataMod, aes(x = f0, y = f1)) + geom_point(aes(color = gender, alpha = 0.01))
```




```
fullMod = lm(gender~f0 + f1 + f2, dataMod)
redMod = lm(gender~f0, dataMod)
anova(redMod, fullMod)
```

```
## Analysis of Variance Table
##
## Model 1: gender ~ f0
## Model 2: gender ~ f0 + f1 + f2
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1   8562 1116.0
## 2   8560 1097.3  2    18.742 73.103 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
test = lm(gender~f0, dataMod)
summary(test)
```

```
##
## Call:
## lm(formula = gender ~ f0, data = dataMod)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.88586 -0.24021  0.02176  0.19727  1.27221
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)  1.437e+00  1.256e-02  114.45   <2e-16 ***
## f0          -6.405e-03  7.464e-05  -85.82   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.361 on 8562 degrees of freedom
## Multiple R-squared:  0.4624, Adjusted R-squared:  0.4624
## F-statistic:  7365 on 1 and 8562 DF,  p-value: < 2.2e-16
```

```
test2 = lm(gender~f0 + f1, dataMod)
summary(test2)
```

```
##
## Call:
## lm(formula = gender ~ f0 + f1, data = dataMod)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.89008 -0.23932  0.02505  0.19688  1.27451
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.503e+00  1.743e-02  86.185  < 2e-16 ***
## f0          -6.413e-03  7.453e-05 -86.044  < 2e-16 ***
## f1          -1.304e-04  2.420e-05  -5.387 7.37e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3604 on 8561 degrees of freedom
## Multiple R-squared:  0.4642, Adjusted R-squared:  0.4641
## F-statistic:  3709 on 2 and 8561 DF,  p-value: < 2.2e-16
```

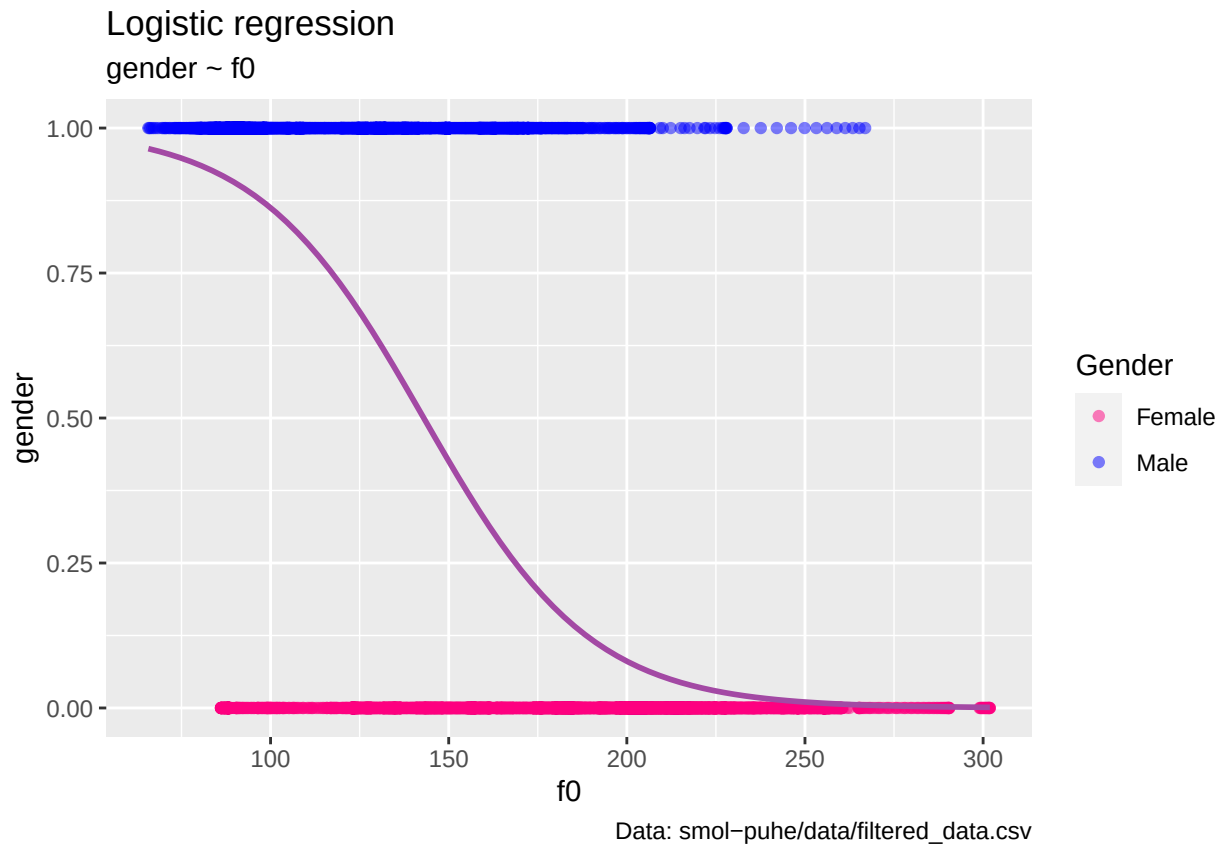
```
test3 = lm(gender~f0 + f1 + f0*f1, dataMod)
summary(test3)
```

```
##
## Call:
## lm(formula = gender ~ f0 + f1 + f0 * f1, data = dataMod)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.90859 -0.23638  0.01256  0.21176  1.27061
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.846e+00  3.979e-02  46.392   <2e-16 ***
## f0          -8.392e-03  2.195e-04 -38.240   <2e-16 ***
## f1          -8.241e-04  7.628e-05 -10.804   <2e-16 ***
## f0:f1        4.007e-06  4.181e-07   9.584   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3585 on 8560 degrees of freedom
## Multiple R-squared:  0.4699, Adjusted R-squared:  0.4697
## F-statistic:  2530 on 3 and 8560 DF,  p-value: < 2.2e-16
```

Logistic Regression

```
## Logistic regression
## gender ~ f0

ggplot(data, aes(x=f0, y=gender)) +
  geom_point(alpha=.5, aes(color = cut(data$gender, c(-1, 0.5, 1)))) +
  scale_color_manual(name = "Gender",
                     values = c("(-1,0.5]" = "#ff0080",
                                "(0.5,1]" = "#0000ff"),
                     labels = c("Female", "Male")) +
  stat_smooth(method="glm", se=FALSE,
              method.args = list(family=binomial), col="#a349a4") +
  labs(title = "Logistic regression",
       subtitle = "gender ~ f0",
       caption = "Data: smol-puhe/data/filtered_data.csv")
```

```
## `geom_smooth()` using formula 'y ~ x'
```



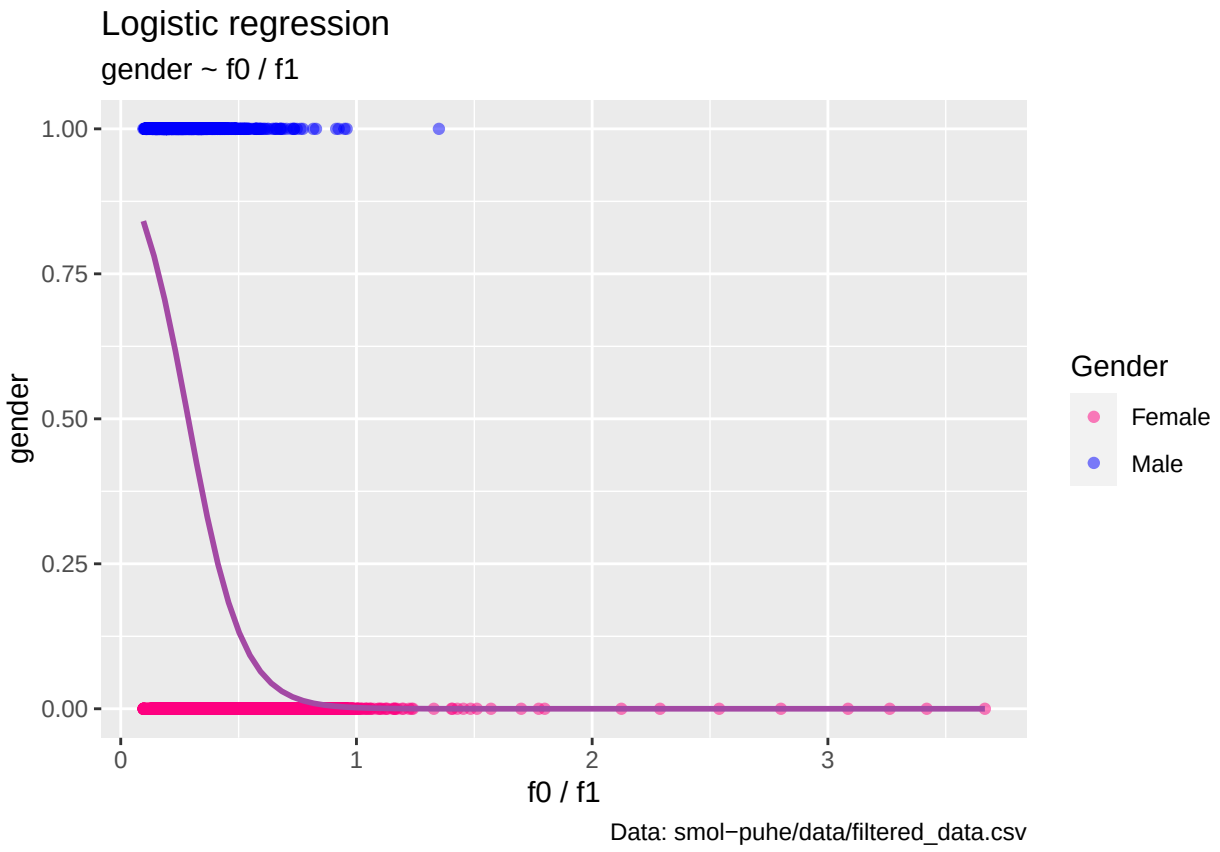

```
# ggsave("logistic_gender_f0.png")

model_f0 <- glm(gender~f0, data = data)
summary(model_f0)
```

```
##
## Call:
## glm(formula = gender ~ f0, data = data)
```

```
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -0.88586  -0.24021   0.02176   0.19727   1.27221
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.437e+00  1.256e-02  114.45   <2e-16 ***
## f0          -6.405e-03  7.464e-05  -85.82   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.1303468)
##
##     Null deviance: 2076  on 8563  degrees of freedom
## Residual deviance: 1116  on 8562  degrees of freedom
## AIC: 6857.9
##
## Number of Fisher Scoring iterations: 2
```

```
## Logistic regression ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## gender ~ f0 / f1

data$f0_over_f1 <- data$f0 / data$f1

ggplot(data, aes(x=f0_over_f1, y=gender)) +
  geom_point(alpha=.5, aes(color = cut(data$gender, c(-1, 0.5, 1)))) +
  scale_color_manual(name = "Gender",
                     values = c("(-1,0.5]" = "#ff0080",
                                "(0.5,1]" = "#0000ff"),
                     labels = c("Female", "Male")) +
  stat_smooth(method="glm", se=FALSE,
              method.args = list(family=binomial), col="#a349a4") +
  labs(title = "Logistic regression",
       subtitle = "gender ~ f0 / f1",
       caption = "Data: smol-puhe/data/filtered_data.csv") +
  xlab("f0 / f1")
```

```
## `geom_smooth()` using formula 'y ~ x'
```



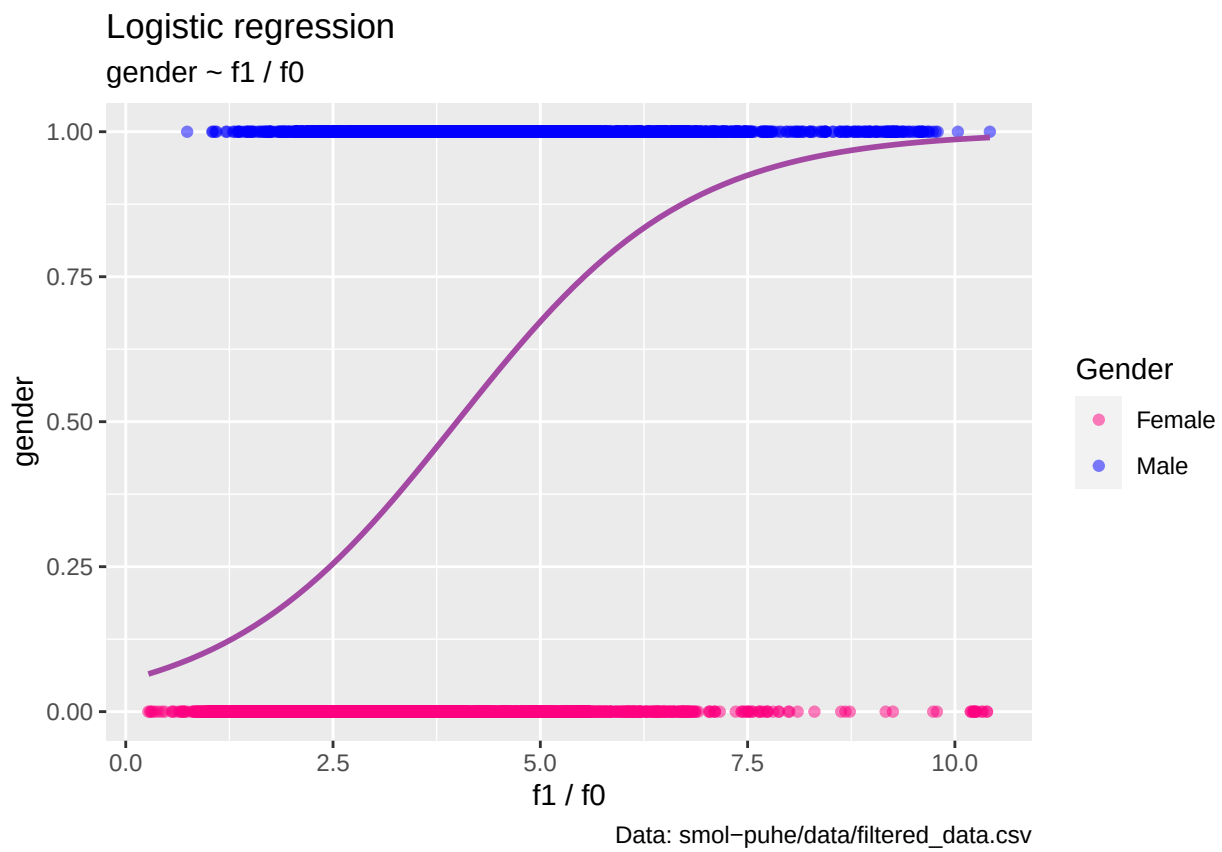

```
# ggsave("logistic_gender_f0_over_f1.png")

model_f0_over_f1 <- glm(gender~f0_over_f1, data = data, family="binomial")
summary(model_f0_over_f1)
```

```
##
## Call:
## glm(formula = gender ~ f0_over_f1, family = "binomial", data = data)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9164  -0.9478  -0.2153   0.9317   4.3118
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.50409    0.07563   33.11   <2e-16 ***
## f0_over_f1  -8.74146    0.23893  -36.59   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 11611.0  on 8563  degrees of freedom
## Residual deviance:  9137.9  on 8562  degrees of freedom
## AIC: 9141.9
##
```

```
## Number of Fisher Scoring iterations: 5
```

```
## Logistic regression ##########################################################
## gender ~ f1 / f0

data$f1_over_f0 = data$f1 / data$f0

ggplot(data, aes(x=f1_over_f0, y=gender)) +
  geom_point(alpha=.5, aes(color = cut(data$gender, c(-1, 0.5, 1)))) +
  scale_color_manual(name = "Gender",
                     values = c("(-1,0.5]" = "#ff0080",
                                "(0.5,1]" = "#0000ff"),
                     labels = c("Female", "Male")) +
  stat_smooth(method="glm", se=FALSE,
              method.args = list(family=binomial),
              col="#a349a4") +
  labs(title = "Logistic regression",
       subtitle = "gender ~ f1 / f0",
       caption = "Data: smol-puhe/data/filtered_data.csv") +
  xlab("f1 / f0")
```

```
## `geom_smooth()` using formula 'y ~ x'
```

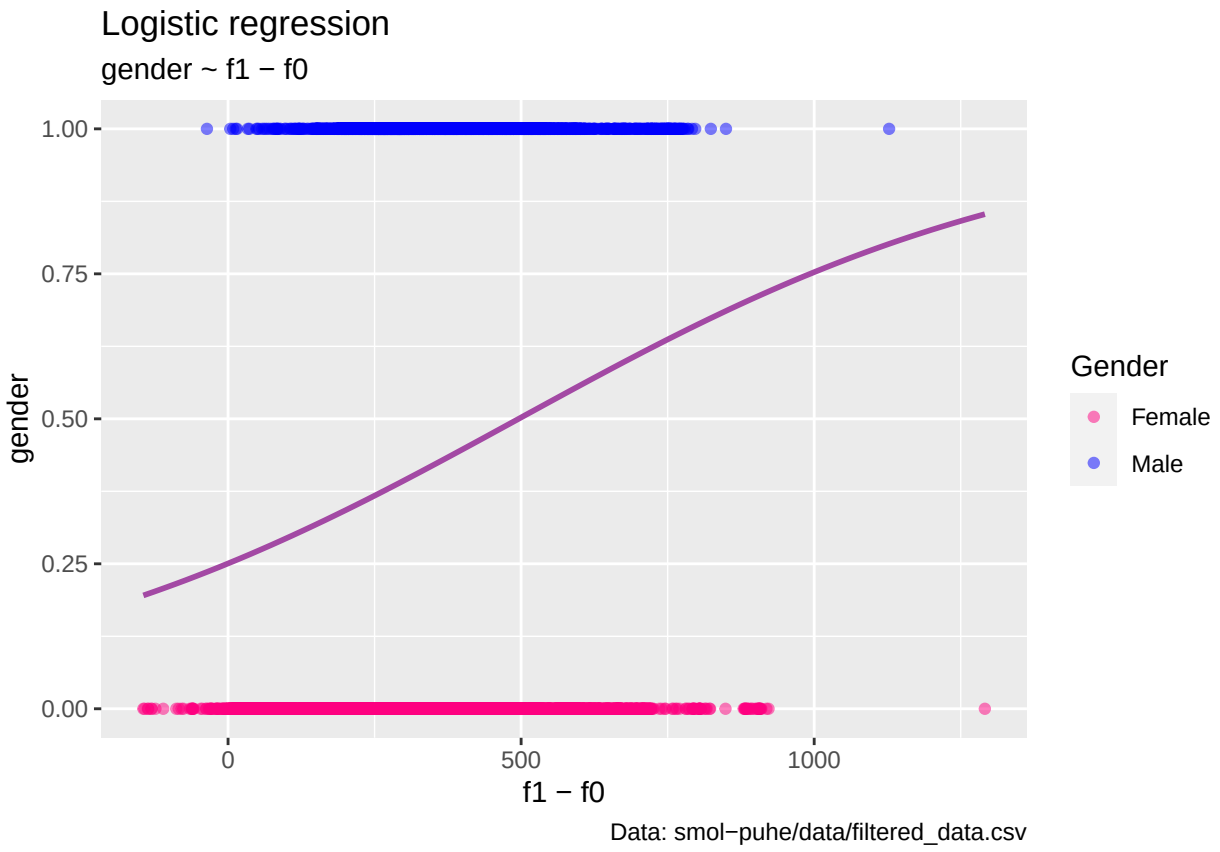



```
# ggsave("logistic_gender_f1_over_f0.png")

model_f1_over_f0 <- glm(gender~f1_over_f0, data = data, family="binomial")
summary(model_f1_over_f0)
```

```
##
## Call:
## glm(formula = gender ~ f1_over_f0, family = "binomial", data = data)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.0306  -0.8531  -0.5374   0.9956   2.2022
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.86315    0.06974  -41.05   <2e-16 ***
## f1_over_f0   0.71667    0.01873   38.27   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 11611  on 8563  degrees of freedom
## Residual deviance:  9539  on 8562  degrees of freedom
## AIC: 9543
##
## Number of Fisher Scoring iterations: 4
```

```
## Logistic regression ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## gender ~ f1 - f0

data$f1_minus_f0 = data$f1 - data$f0

ggplot(data, aes(x=f1_minus_f0, y=gender)) +
  geom_point(alpha=.5, aes(color = cut(data$gender, c(-1, 0.5, 1)))) +
  scale_color_manual(name = "Gender",
                     values = c("(-1,0.5]" = "#ff0080",
                                "(0.5,1]" = "#0000ff"),
                     labels = c("Female", "Male")) +
  stat_smooth(method="glm", se=FALSE,
              method.args = list(family=binomial),
              col="#a349a4") +
  labs(title = "Logistic regression",
       subtitle = "gender ~ f1 - f0",
       caption = "Data: smol-puhe/data/filtered_data.csv") +
  xlab("f1 - f0")
```

```
## `geom_smooth()` using formula 'y ~ x'
```



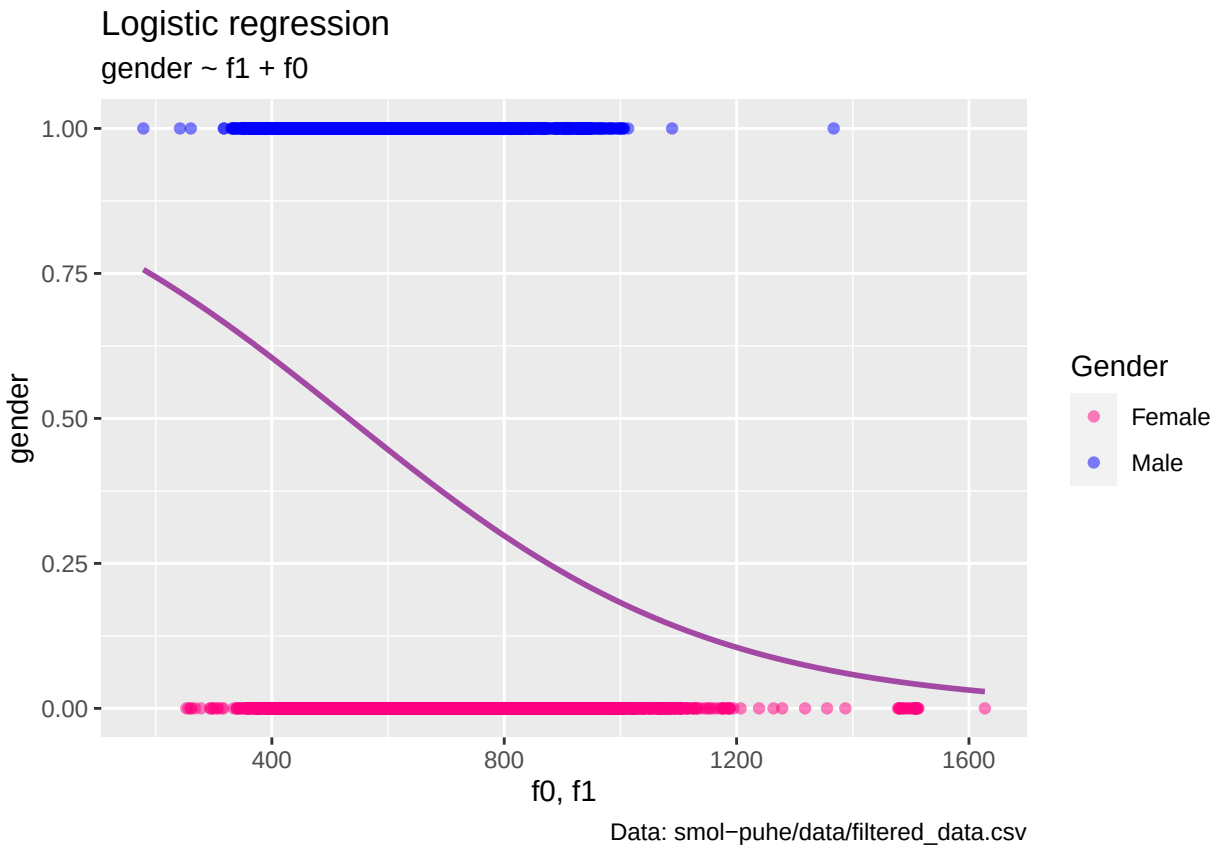

```
# ggsave("logistic_gender_f1_minus_f0.png")

model_f1_minus_f0 <- glm(gender~f1_minus_f0, data = data, family="binomial")
summary(model_f1_minus_f0)
```

```
##
## Call:
## glm(formula = gender ~ f1_minus_f0, family = "binomial", data = data)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9579  -1.0346  -0.8241   1.2815   1.6996
##
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.0956149  0.0510089  -21.48   <2e-16 ***
## f1_minus_f0  0.0022098  0.0001346   16.42   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 11611  on 8563  degrees of freedom
## Residual deviance: 11329  on 8562  degrees of freedom
## AIC: 11333
##
```

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

```
## Logistic regression ##########################################################
## gender ~ f0 + f1

ggplot(data, aes(x=f0 + f1, y=gender)) +
  geom_point(alpha=.5, aes(color = cut(data$gender, c(-1, 0.5, 1)))) +
  scale_color_manual(name = "Gender",
                     values = c("(-1,0.5]" = "#ff0080",
                                "(0.5,1]" = "#0000ff"),
                     labels = c("Female", "Male")) +
  stat_smooth(method="glm", se=FALSE,
              method.args = list(family=binomial),
              col="#a349a4") +
  labs(title = "Logistic regression",
       subtitle = "gender ~ f1 + f0",
       caption = "Data: smol-puhe/data/filtered_data.csv") +
  xlab("f0, f1")
```

```
## `geom_smooth()` using formula 'y ~ x'
```




```
# ggsave("logistic_gender_f1_minus_f0.png")

model <- glm(gender~f0 + f1 + f0*f1, data = data, family="binomial")
summary(model)
```

```
##
## Call:
```

```
## glm(formula = gender ~ f0 + f1 + f0 * f1, family = "binomial",
##     data = data)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.3819  -0.5314  -0.2197   0.4901   3.2730
##
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  9.773e+00  4.378e-01  22.321  < 2e-16 ***
## f0          -6.141e-02  2.757e-03 -22.274  < 2e-16 ***
## f1          -6.988e-03  7.830e-04  -8.924  < 2e-16 ***
## f0:f1        3.561e-05  5.029e-06   7.080 1.44e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 11611.0  on 8563  degrees of freedom
## Residual deviance:  6581.4  on 8560  degrees of freedom
## AIC: 6589.4
##
## Number of Fisher Scoring iterations: 5
```

Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.