

choosing_thresholds

Ann Cirincione

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Finding thresholds that have the same FPR/FNR

```
library(reshape2)
library(ggplot2)
library(dplyr)
library(stringr)
library(tidyr)
# Function that calculates FPR and FNR at different thresholds
get_threshold_df <- function(df, threshold, attr, output_df){
  threshold_df <- ungroup(df) %>%
    mutate(received_h1n1 = case_when(h1n1_pred >= threshold ~ 1, h1n1_pred < threshold ~ 0),
           received_seasonal = case_when(seasonal_pred >= threshold ~ 1, seasonal_pred < threshold ~ 0))
  tp_h1n1 <- nrow(filter(threshold_df, received_h1n1==1 & h1n1_vaccine == 1))
  fp_h1n1 <- nrow(filter(threshold_df, received_h1n1==1 & h1n1_vaccine == 0))
  tn_h1n1 <- nrow(filter(threshold_df, received_h1n1==0 & h1n1_vaccine == 0))
  fn_h1n1 <- nrow(filter(threshold_df, received_h1n1==0 & h1n1_vaccine == 1))

  tp_seasonal <- nrow(filter(threshold_df, received_seasonal==1 & seasonal_vaccine == 1))
  fp_seasonal <- nrow(filter(threshold_df, received_seasonal==1 & seasonal_vaccine == 0))
  tn_seasonal <- nrow(filter(threshold_df, received_seasonal==0 & seasonal_vaccine == 0))
  fn_seasonal <- nrow(filter(threshold_df, received_seasonal==0 & seasonal_vaccine == 1))

  output_df[nrow(output_df)+1,] <- c(threshold, attr, "h1n1",
                                     (fp_h1n1/(fp_h1n1+tn_h1n1)),
                                     (fn_h1n1/(fn_h1n1+tp_h1n1)),
                                     (tp_h1n1/(tp_h1n1+fp_h1n1)))
  output_df[nrow(output_df)+1,] <- c(threshold, attr, "seasonal",
                                     (fp_seasonal/(fp_seasonal+tn_seasonal)),
                                     (fn_seasonal/(fn_seasonal+tp_seasonal)),
                                     (tp_seasonal/(tp_seasonal+fp_seasonal)))

  return(output_df)
}

log_reg_predictions <- read.csv("C:/Users/ANN/PycharmProjects/COS534/Final_Project/log_reg_predictions.
  rename(h1n1_pred=h1n1_vaccine.1, seasonal_pred=seasonal_vaccine.1)
```

Creating threshold dataframes

```
# Getting values for varying thresholds for race, sex, and age group
B_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
```

```

FPR=numeric(), FNR=numeric(), PPV=numeric())
W_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
H_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
X_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())

M_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
F_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())

A1_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
A2_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
A3_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
A4_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())
A5_threshold <- data.frame(threshold=numeric(), attr=character(), vaccine=character(),
FPR=numeric(), FNR=numeric(), PPV=numeric())

```

Calculating thresholds

```

for(i in seq(0.1, 0.9, 0.1)){
  B_threshold <- get_threshold_df(filter(log_reg_predictions, race == "Black"), i,
"Black", B_threshold)
  W_threshold <- get_threshold_df(filter(log_reg_predictions, race == "White"), i,
"White", W_threshold)
  H_threshold <- get_threshold_df(filter(log_reg_predictions, race == "Hispanic"), i,
"Hispanic", H_threshold)
  X_threshold <- get_threshold_df(filter(log_reg_predictions, race == "Other or Multiple"), i,
"Other or Multiple", X_threshold)

  M_threshold <- get_threshold_df(filter(log_reg_predictions, sex == "Male"), i,
"Male", M_threshold)
  F_threshold <- get_threshold_df(filter(log_reg_predictions, sex == "Female"), i,
"Female", F_threshold)

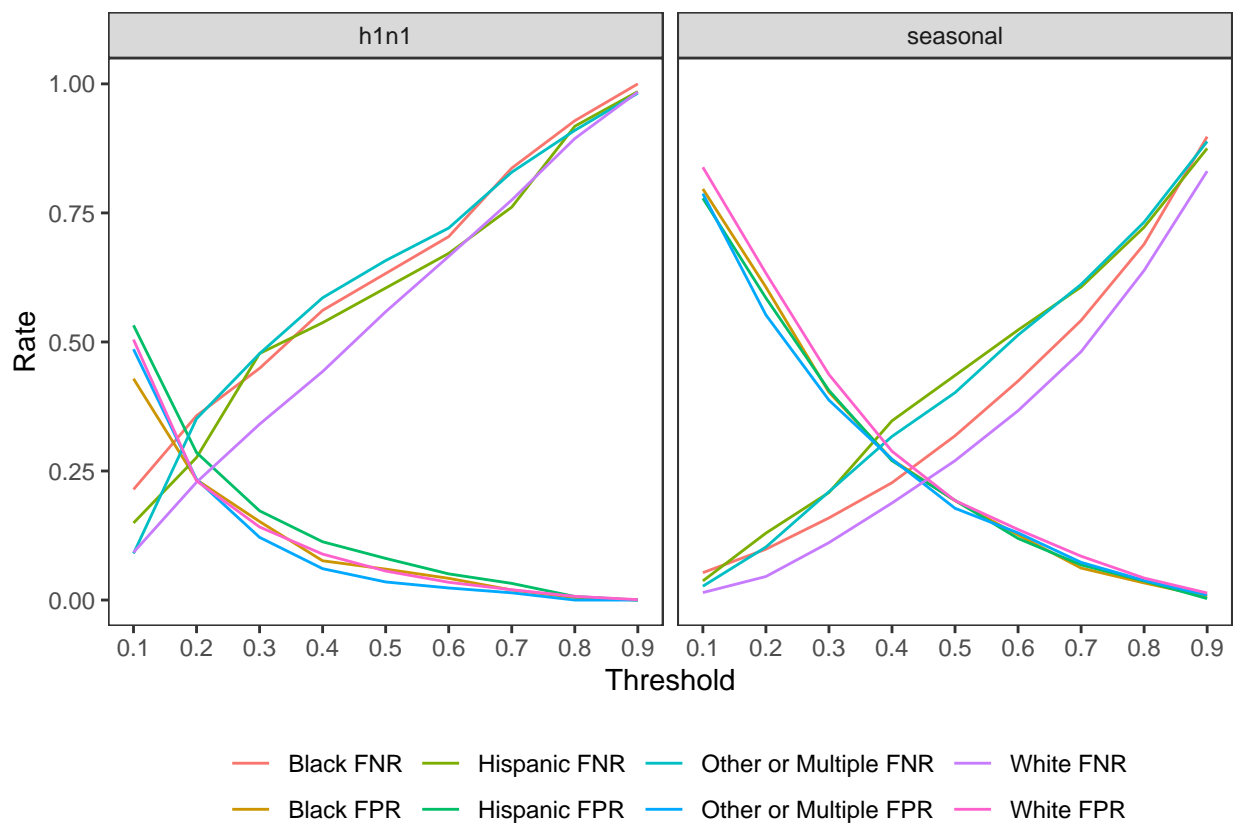
  A1_threshold <- get_threshold_df(filter(log_reg_predictions, age_group == "18 - 34 Years"), i,
"18 - 34 Years", A1_threshold)
  A2_threshold <- get_threshold_df(filter(log_reg_predictions, age_group == "35 - 44 Years"), i,
"35 - 44 Years", A2_threshold)
  A3_threshold <- get_threshold_df(filter(log_reg_predictions, age_group == "45 - 54 Years"), i,
"45 - 54 Years", A3_threshold)
  A4_threshold <- get_threshold_df(filter(log_reg_predictions, age_group == "55 - 64 Years"), i,
"55 - 64 Years", A4_threshold)
  A5_threshold <- get_threshold_df(filter(log_reg_predictions, age_group == "65+ Years"), i,
"65+ Years", A5_threshold)
}

```

```
merged_thresholds <- rbind.data.frame(B_threshold, W_threshold, H_threshold, X_threshold,
                                     M_threshold, F_threshold,
                                     A1_threshold, A2_threshold, A3_threshold, A4_threshold,
                                     A5_threshold, stringsAsFactors = FALSE) %>%
  mutate(threshold=as.numeric(threshold), FPR=as.numeric(FPR), FNR=as.numeric(FNR), PPV=as.numeric(PPV))
```

Plotting for race

```
ggplot(data = filter(merged_thresholds, attr %in% unique(log_reg_predictions$race)) %>%
  select(-PPV) %>%
  melt(id.vars=c("threshold", "attr", "vaccine")) %>%
  unite("condition", c(attr, variable), sep=" ") %>%
  mutate(threshold=as.numeric(threshold), value=as.numeric(value))) +
  geom_line(aes(x=threshold, y=value, color=condition)) +
  facet_wrap(~vaccine) +
  scale_x_continuous(breaks=seq(0.1, 0.9, 0.1)) +
  labs(x="Threshold", y="Rate", color="") +
  theme_bw() +
  theme(panel.grid = element_blank(), legend.position = "bottom")
```



Choosing thresholds for H1N1 vaccine

```
print(paste("At a threshold of 0.4, for Black H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="Black" & vaccine=="h1n1")$FPR, digits=3),
```

```

", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Black" & vaccine=="h1n1")$FNR, digits=3),
", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Black" & vaccine=="h1n1")$PPV, digits=3),
sep = ""))

```

[1] "At a threshold of 0.4, for Black H1N1 vaccine: FPR=0.076, FNR=0.561, PPV=0.478"

```

print(paste("At a threshold of 0.5, for White H1N1 vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.5 & attr=="White" & vaccine=="h1n1")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="White" & vaccine=="h1n1")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="White" & vaccine=="h1n1")$PPV, digits=3),
            sep = ""))

```

[1] "At a threshold of 0.5, for White H1N1 vaccine: FPR=0.056, FNR=0.559, PPV=0.687"

```

print(paste("At a threshold of 0.5, for Hispanic H1N1 vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.5 & attr=="Hispanic" & vaccine=="h1n1")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="Hispanic" & vaccine=="h1n1")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="Hispanic" & vaccine=="h1n1")$PPV, digits=3),
            sep = ""))

```

[1] "At a threshold of 0.5, for Hispanic H1N1 vaccine: FPR=0.081, FNR=0.604, PPV=0.602"

```

print(paste("At a threshold of 0.4, for Other/Multiple H1N1 vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Other or Multiple" & vaccine=="h1n1")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Other or Multiple" & vaccine=="h1n1")$FNR, d
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Other or Multiple" & vaccine=="h1n1")$PPV, d
            sep = ""))

```

[1] "At a threshold of 0.4, for Other/Multiple H1N1 vaccine: FPR=0.061, FNR=0.586, PPV=0.639"

At a threshold of 0.4, for Black H1N1 vaccine: FPR=0.076, FNR=0.561, PPV=0.478

At a threshold of 0.5, for White H1N1 vaccine: FPR=0.056, FNR=0.559, PPV=0.687

At a threshold of 0.5, for Hispanic H1N1 vaccine: FPR=0.081, FNR=0.604, PPV=0.602

At a threshold of 0.4, for Other/Multiple H1N1 vaccine: FPR=0.061, FNR=0.586, PPV=0.639

Choosing thresholds for seasonal vaccine

```

print(paste("At a threshold of 0.4, for Black seasonal vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Black" & vaccine=="seasonal")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Black" & vaccine=="seasonal")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="Black" & vaccine=="seasonal")$PPV, digits=3),
            sep = ""))

```

```
## [1] "At a threshold of 0.4, for Black seasonal vaccine: FPR=0.272, FNR=0.227, PPV=0.624"
print(paste("At a threshold of 0.4, for White seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="White" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="White" & vaccine=="seasonal")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="White" & vaccine=="seasonal")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for White seasonal vaccine: FPR=0.288, FNR=0.188, PPV=0.727"
print(paste("At a threshold of 0.4, for Hispanic seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="Hispanic" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Hispanic" & vaccine=="seasonal")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Hispanic" & vaccine=="seasonal")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Hispanic seasonal vaccine: FPR=0.27, FNR=0.347, PPV=0.597"
print(paste("At a threshold of 0.4, for Other/Multiple seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="Other or Multiple" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Other or Multiple" & vaccine=="seasonal")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Other or Multiple" & vaccine=="seasonal")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Other/Multiple seasonal vaccine: FPR=0.273, FNR=0.317, PPV=0.64"
```

At a threshold of 0.4, for Black seasonal vaccine: FPR=0.272, FNR=0.227, PPV=0.624

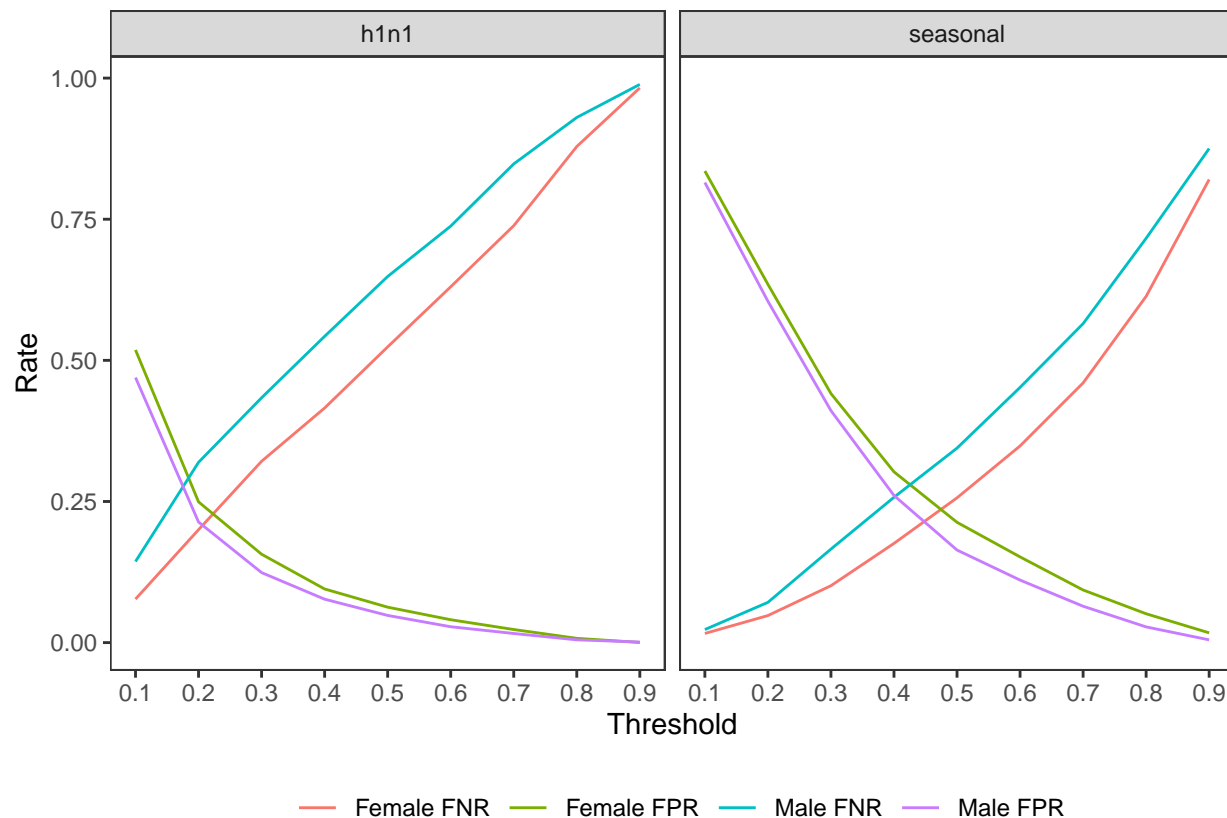
At a threshold of 0.4, for White seasonal vaccine: FPR=0.288, FNR=0.188, PPV=0.727

At a threshold of 0.4, for Hispanic seasonal vaccine: FPR=0.27, FNR=0.347, PPV=0.597

At a threshold of 0.4, for Other/Multiple seasonal vaccine: FPR=0.273, FNR=0.317, PPV=0.64

Plotting based on sex

```
ggplot(data = filter(merged_thresholds, attr %in% unique(log_reg_predictions$sex)) %>%
  select(-PPV) %>%
  melt(id.vars=c("threshold", "attr", "vaccine")) %>%
  unite("condition", c(attr, variable), sep=" ") %>%
  mutate(threshold=as.numeric(threshold), value=as.numeric(value))) +
  geom_line(aes(x=threshold, y=value, color=condition)) +
  facet_wrap(~vaccine) +
  scale_x_continuous(breaks=seq(0.1, 0.9, 0.1)) +
  labs(x="Threshold", y="Rate", color="") +
  theme_bw() +
  theme(panel.grid = element_blank(), legend.position = "bottom")
```



Choosing thresholds for H1N1 vaccine

```
print(paste("At a threshold of 0.4, for Male H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="h1n1")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="h1n1")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="h1n1")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Male H1N1 vaccine: FPR=0.077, FNR=0.543, PPV=0.6"
```

```
print(paste("At a threshold of 0.5, for Female H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="h1n1")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="h1n1")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="h1n1")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.5, for Female H1N1 vaccine: FPR=0.063, FNR=0.524, PPV=0.682"
```

At a threshold of 0.4, for Male H1N1 vaccine: FPR=0.077, FNR=0.543, PPV=0.6

At a threshold of 0.5, for Female H1N1 vaccine: FPR=0.063, FNR=0.524, PPV=0.682

Choosing thresholds for seasonal vaccine

```
print(paste("At a threshold of 0.4, for Male seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="seasonal")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="Male" & vaccine=="seasonal")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Male seasonal vaccine: FPR=0.261, FNR=0.257, PPV=0.678"
```

```
print(paste("At a threshold of 0.5, for Female seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="seasonal")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="Female" & vaccine=="seasonal")$PPV, digits=3),
  sep = ""))
```

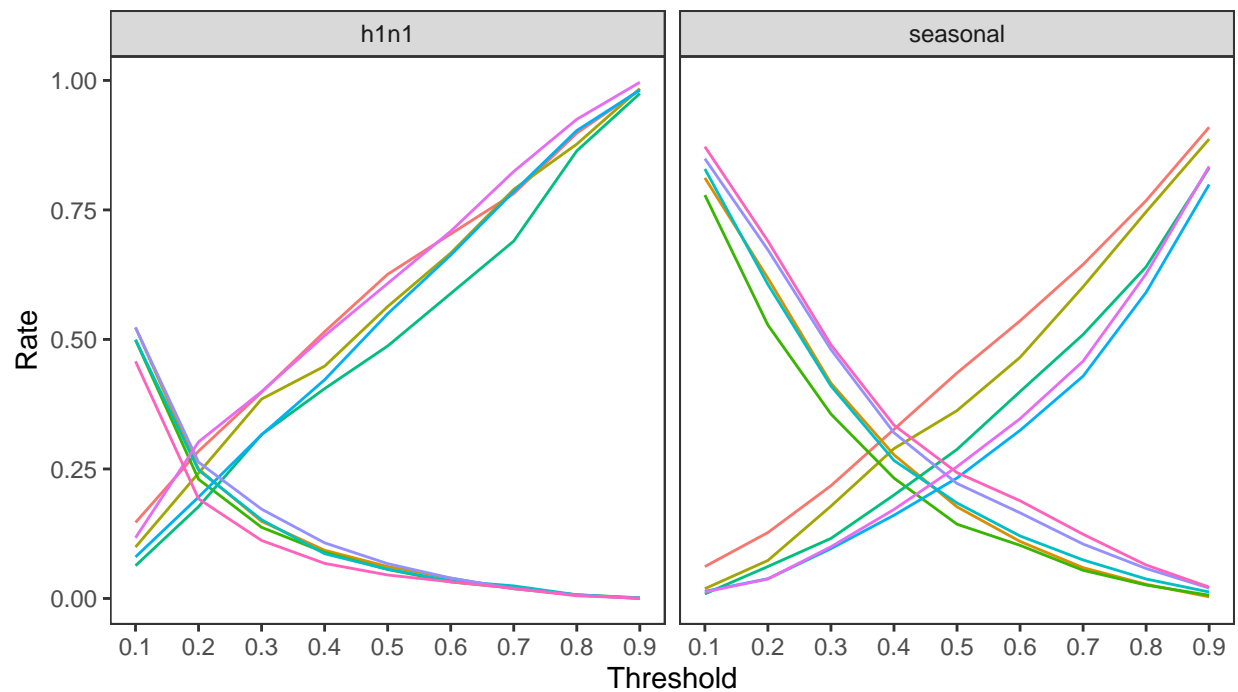
```
## [1] "At a threshold of 0.5, for Female seasonal vaccine: FPR=0.213, FNR=0.256, PPV=0.772"
```

At a threshold of 0.4, for Male seasonal vaccine: FPR=0.261, FNR=0.257, PPV=0.678

At a threshold of 0.5, for Female seasonal vaccine: FPR=0.213, FNR=0.256, PPV=0.772

Plotting based on age group

```
ggplot(data = filter(merged_thresholds, attr %in% unique(log_reg_predictions$age_group))) %>%
  select(-PPV) %>%
  melt(id.vars=c("threshold", "attr", "vaccine")) %>%
  unite("condition", c(attr, variable), sep=" ") %>%
  mutate(threshold=as.numeric(threshold), value=as.numeric(value))) +
  geom_line(aes(x=threshold, y=value, color=condition)) +
  facet_wrap(~vaccine) +
  #geom_vline(xintercept = 5, color="gray") +
  #geom_vline(xintercept = 7, color="gray", linetype="dashed") +
  scale_x_continuous(breaks=seq(0.1, 0.9, 0.1)) +
  labs(x="Threshold", y="Rate", color="") +
  theme_bw() +
  theme(panel.grid = element_blank(), legend.position = "bottom")
```



— 18 – 34 Years FNR — 35 – 44 Years FNR — 45 – 54 Years FNR — 55 – 64 Years FNR — 65+ Years FNR
 — 18 – 34 Years FPR — 35 – 44 Years FPR — 45 – 54 Years FPR — 55 – 64 Years FPR — 65+ Years FPR

Choosing thresholds for H1N1 vaccine

```
print(paste("At a threshold of 0.4, for Age 18-34 H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="18 - 34 Years" & vaccine=="h1n1")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="18 - 34 Years" & vaccine=="h1n1")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="18 - 34 Years" & vaccine=="h1n1")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Age 18-34 H1N1 vaccine: FPR=0.093, FNR=0.515, PPV=0.555"
```

```
print(paste("At a threshold of 0.4, for Age 35-44 H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.4 & attr=="35 - 44 Years" & vaccine=="h1n1")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="35 - 44 Years" & vaccine=="h1n1")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.4 & attr=="35 - 44 Years" & vaccine=="h1n1")$PPV, digits=3),
  sep = ""))
```

```
## [1] "At a threshold of 0.4, for Age 35-44 H1N1 vaccine: FPR=0.089, FNR=0.448, PPV=0.602"
```

```
print(paste("At a threshold of 0.5, for Age 45-54 H1N1 vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="h1n1")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="h1n1")$FNR, digits=3),
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="h1n1")$PPV, digits=3),
  sep = ""))
```



```

", FNR=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="45 - 54 Years" & vaccine=="h1n1")$FNR, digits=3),
", PPV=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="45 - 54 Years" & vaccine=="h1n1")$PPV, digits=3),
sep = ""))

```

```
## [1] "At a threshold of 0.5, for Age 45-54 H1N1 vaccine: FPR=0.056, FNR=0.487, PPV=0.672"
```

```

print(paste("At a threshold of 0.5, for Age 55-64 H1N1 vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.5 & attr=="55 - 64 Years" & vaccine=="h1n1")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="55 - 64 Years" & vaccine=="h1n1")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.5 & attr=="55 - 64 Years" & vaccine=="h1n1")$PPV, digits=3),
            sep = ""))

```

```
## [1] "At a threshold of 0.5, for Age 55-64 H1N1 vaccine: FPR=0.067, FNR=0.55, PPV=0.675"
```

```

print(paste("At a threshold of 0.4, for Age 65+ H1N1 vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.4 & attr=="65+ Years" & vaccine=="h1n1")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="65+ Years" & vaccine=="h1n1")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="65+ Years" & vaccine=="h1n1")$PPV, digits=3),
            sep = ""))

```

```
## [1] "At a threshold of 0.4, for Age 65+ H1N1 vaccine: FPR=0.068, FNR=0.507, PPV=0.695"
```

At a threshold of 0.4, for Age 18-34 H1N1 vaccine: FPR=0.093, FNR=0.515, PPV=0.555

At a threshold of 0.4, for Age 35-44 H1N1 vaccine: FPR=0.089, FNR=0.448, PPV=0.602

At a threshold of 0.5, for Age 45-54 H1N1 vaccine: FPR=0.056, FNR=0.487, PPV=0.672

At a threshold of 0.5, for Age 55-64 H1N1 vaccine: FPR=0.067, FNR=0.55, PPV=0.675

At a threshold of 0.4, for Age 65+ H1N1 vaccine: FPR=0.068, FNR=0.507, PPV=0.695

Choosing thresholds for H1N1 vaccine

```

print(paste("At a threshold of 0.4, for Age 18-34 seasonal vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.4 & attr=="18 - 34 Years" & vaccine=="seasonal")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="18 - 34 Years" & vaccine=="seasonal")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="18 - 34 Years" & vaccine=="seasonal")$PPV, digits=3),
            sep = ""))

```

```
## [1] "At a threshold of 0.4, for Age 18-34 seasonal vaccine: FPR=0.277, FNR=0.326, PPV=0.487"
```

```

print(paste("At a threshold of 0.4, for Age 35-44 seasonal vaccine: FPR=",
            round(filter(merged_thresholds,
                        threshold==0.4 & attr=="35 - 44 Years" & vaccine=="seasonal")$FPR, digits=3),
            ", FNR=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="35 - 44 Years" & vaccine=="seasonal")$FNR, digits=3),
            ", PPV=", round(filter(merged_thresholds,
                        threshold==0.4 & attr=="35 - 44 Years" & vaccine=="seasonal")$PPV, digits=3),
            sep = ""))

```

```

sep = "")

## [1] "At a threshold of 0.4, for Age 35-44 seasonal vaccine: FPR=0.232, FNR=0.289, PPV=0.643"
print(paste("At a threshold of 0.5, for Age 45-54 seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="seasonal")$FNR, d
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="45 - 54 Years" & vaccine=="seasonal")$PPV, d
  sep = ""))

## [1] "At a threshold of 0.5, for Age 45-54 seasonal vaccine: FPR=0.184, FNR=0.288, PPV=0.717"
print(paste("At a threshold of 0.5, for Age 55-64 seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="55 - 64 Years" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="55 - 64 Years" & vaccine=="seasonal")$FNR, d
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="55 - 64 Years" & vaccine=="seasonal")$PPV, d
  sep = ""))

## [1] "At a threshold of 0.5, for Age 55-64 seasonal vaccine: FPR=0.222, FNR=0.233, PPV=0.794"
print(paste("At a threshold of 0.5, for Age 65+ seasonal vaccine: FPR=",
  round(filter(merged_thresholds,
    threshold==0.5 & attr=="65+ Years" & vaccine=="seasonal")$FPR, digits=3),
  ", FNR=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="65+ Years" & vaccine=="seasonal")$FNR, digit
  ", PPV=", round(filter(merged_thresholds,
    threshold==0.5 & attr=="65+ Years" & vaccine=="seasonal")$PPV, digit
  sep = ""))

## [1] "At a threshold of 0.5, for Age 65+ seasonal vaccine: FPR=0.243, FNR=0.254, PPV=0.857"

At a threshold of 0.4, for Age 18-34 seasonal vaccine: FPR=0.277, FNR=0.326, PPV=0.487
At a threshold of 0.4, for Age 35-44 seasonal vaccine: FPR=0.232, FNR=0.289, PPV=0.643
At a threshold of 0.5, for Age 45-54 seasonal vaccine: FPR=0.184, FNR=0.288, PPV=0.717
At a threshold of 0.5, for Age 55-64 seasonal vaccine: FPR=0.222, FNR=0.233, PPV=0.794
At a threshold of 0.5, for Age 65+ seasonal vaccine: FPR=0.243, FNR=0.254, PPV=0.857

# Function to calculate distance?
library(foreach)

## Warning: package 'foreach' was built under R version 4.0.5
euc.dist <- function(x1, x2) sqrt(sum((x1 - x2) ^ 2))

best_threshold <- function(df, attribute, attribute2){
  attr_fpr <- filter(df, attr==attribute, vaccine=="h1n1")$FPR
  attr_fnr <- filter(df, attr==attribute, vaccine=="h1n1")$FNR
  dist_mat <- matrix(ncol=9, nrow=9)

  for(i in 1:9){
    x1 <- matrix(rep(c(attr_fpr[i],attr_fnr[i]), 9), nrow = 9, ncol=2, byrow=TRUE)
    x2 <- matrix(c(filter(df, attr==attribute2, vaccine=="h1n1")$FPR,

```

```

        filter(df, attr==attribute2, vaccine=="h1n1")$FNR), nrow = 9, ncol=2, byrow=FALSE)

    dist <- foreach(j = 1:nrow(x1), .combine = c ) %do% euc.dist(x1[j,],x2[j,])
    dist_mat[i,] <- dist
  }
}

```