Analyzing 2022 NFL 4th Down Success by Team

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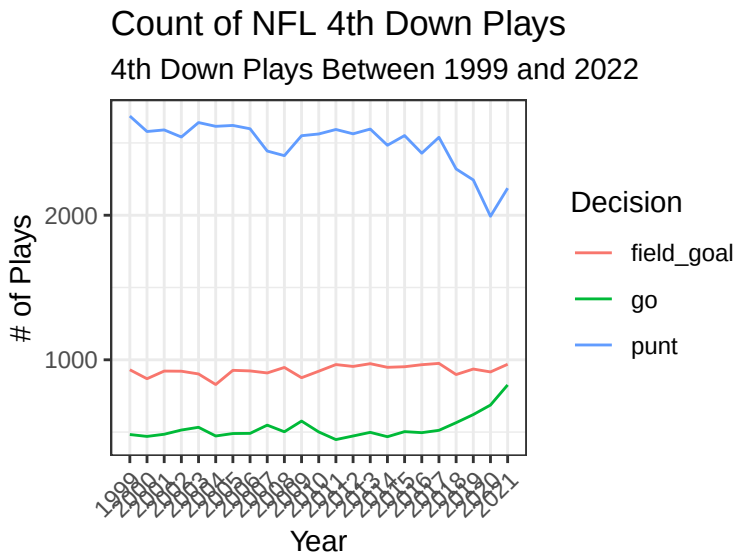
Introduction

Teams across the National Football League have been incorporating analytics into their decision making more and more over the past 20 years. The emergence of analytics has been increasingly dragged by those who think football and numbers should stay separate. Recently, the decision to go for 2 points after scoring a touchdown to go down 6 instead of 7 points late in the game has become a controversy, yet it is an analytically-correct move. We believe the next enhancement of the game in regards to the incorporation of analytics comes one 4th-down decision making. Our project examines NFL 4th down decision making using play-by-play data dating back to 1999. Our goal is to build three models that predict expected win probability added for each of the three decisions coaches have on fourth downs: kick a field goal, punt it, or go for it. Personally, we believe teams should be going for it more and punting less than how they operate currently, but we wish ti support this claim with models.

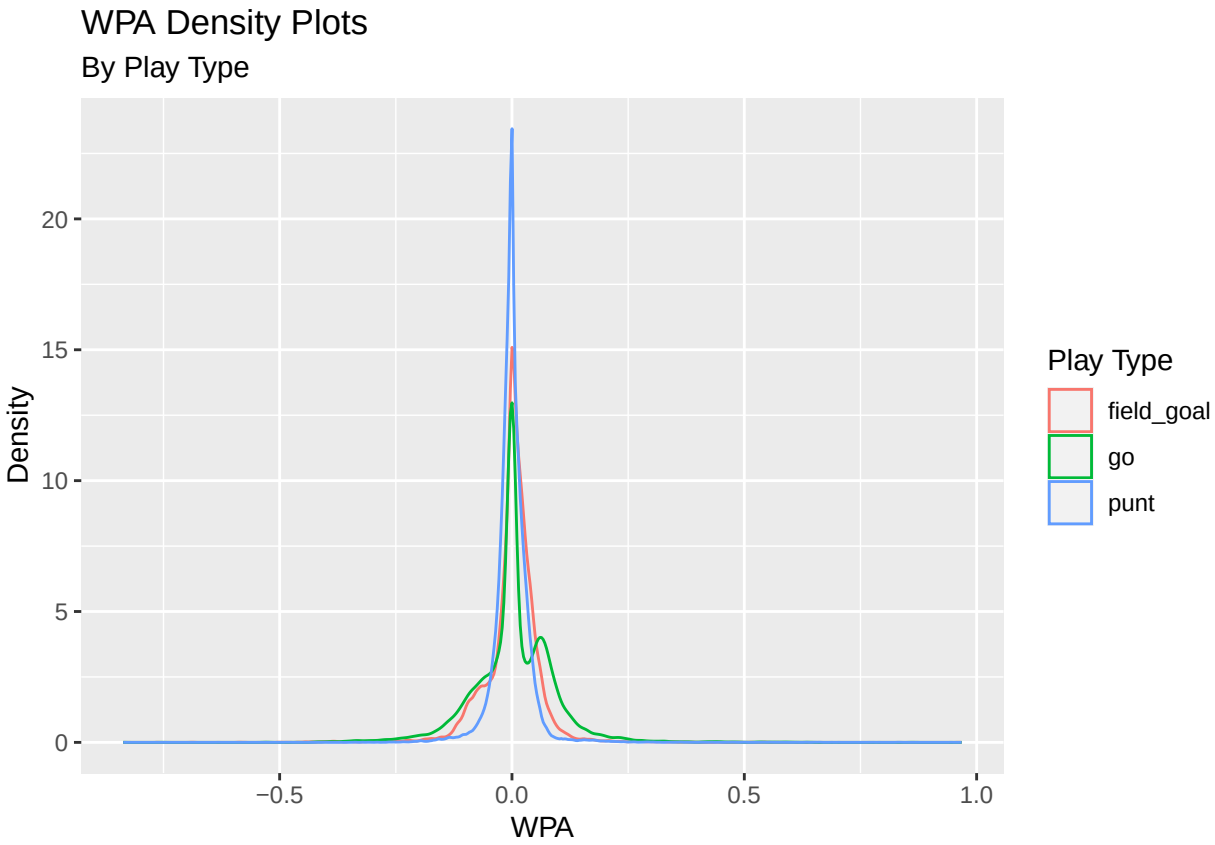
For the purpose of our study, we simplified 4th down decision making, meaning we did not differentiate between run or pass plays, and any trick plays were included as going for it (i.e. lining up in punt formation does not classify it as a punt). To train our data, we used everything that was available to us. Our data comes from the `nflfastR` package which contains data on every play dating back to 1999. After filtering for 4th down plays, we used everything from this season all the way back to 1999. Although we considered basing our project on more recent data, we figured the more data the better and decided to use it all.

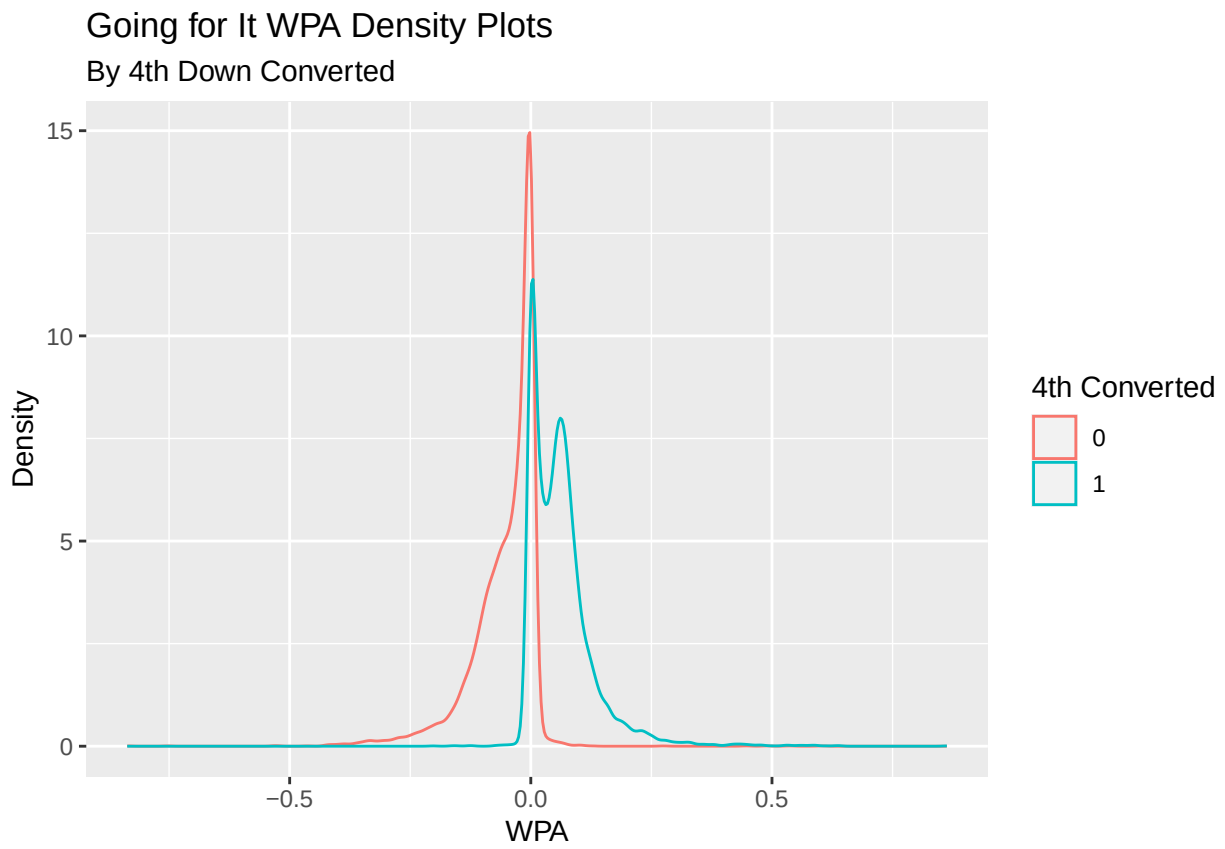
Exploratory Data Analysis

play_type	count	mean_wpa
field_goal	22071	-0.00035
go	12711	0.00393
punt	59007	-0.00044



To get a better idea of what our data looks like, we first wanted to see how much data of each type of play we have. Most 4th down plays are punts, of course, and only a small piece of our dataset is go for it plays, which also makes sense. Looking at the graph however, we can see an uptick in go attempts and a steady decrease in punts over the last 4 full seasons. This hints at the greater picture we are trying to discover: coaches haven't found the right go/punt/kick balance. But they are trending in the right direction.





We can also see that while most of the density plots for WPA are relatively normal, the density plot for going for it on 4th down appears slightly bimodal. This is because a successful 4th down conversion usually leads to a bigger change in WPA than a 4th down failed attempt. While we weren't sure if this was worthy of transforming WPA for the go for it model or all the models, it is something to beware of moving forward.

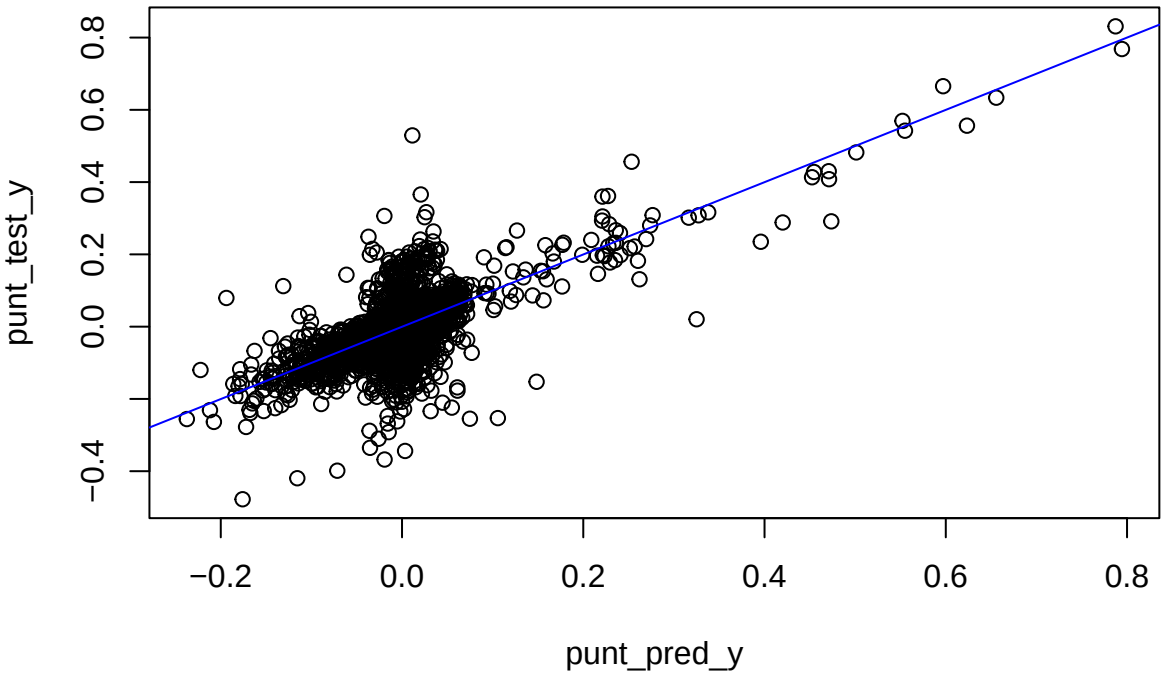
Modeling

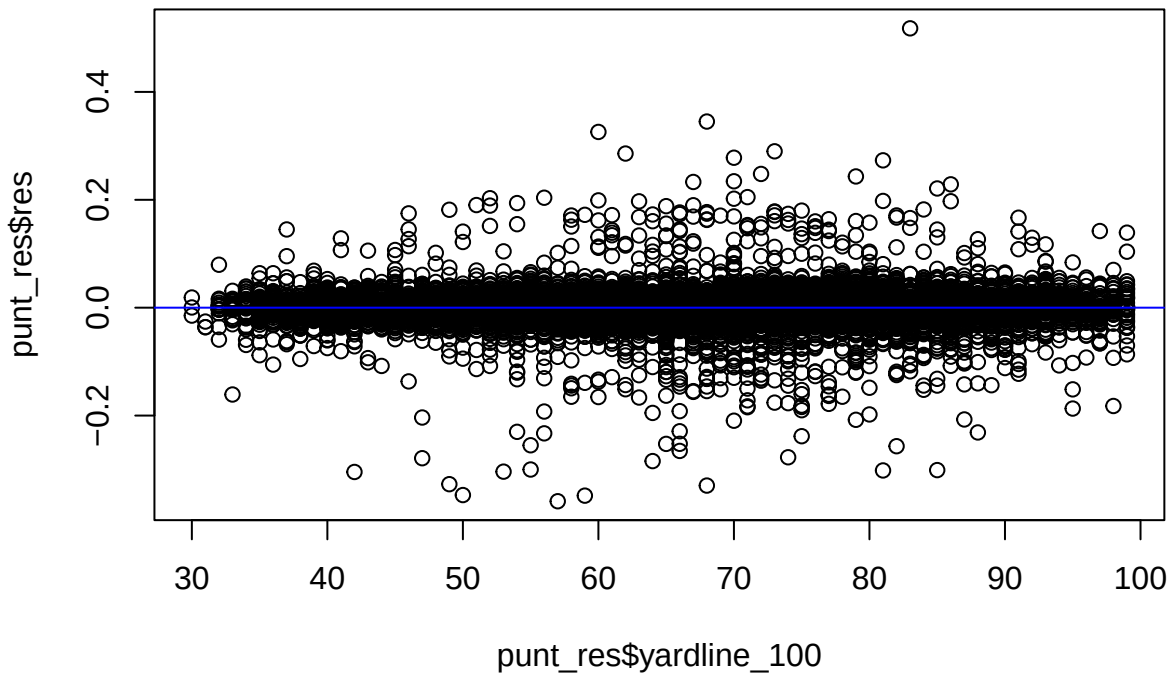
The goal with our models is to create the best possible models for predicting WPA (win probability added) given a certain game state. To do this, we trained 3 separate xGBoost models, each on their own data of one play type. We began by training a baseline xgboost model as well as a Lasso and Ridge regression model for each play type. After examining the MSEs of the models, the xgboost baseline model performed much better than both the ridge and lasso optimal models. After we decided to use xgboost for our final model, we played around with the parameters of the model to try and achieve the best predictive model possible.

[section on the reason we chose xgboost] We split the data for each model into train and test sets using 70-30 splits and then attempted to minimize the RMSE through adjusting model parameters. We also tested lasso and ridge regression models, just to make sure we were fitting the best possible type of model.

Punt Model

```
## [1] "XG Boost RMSE: 0.0293780247141433"
```

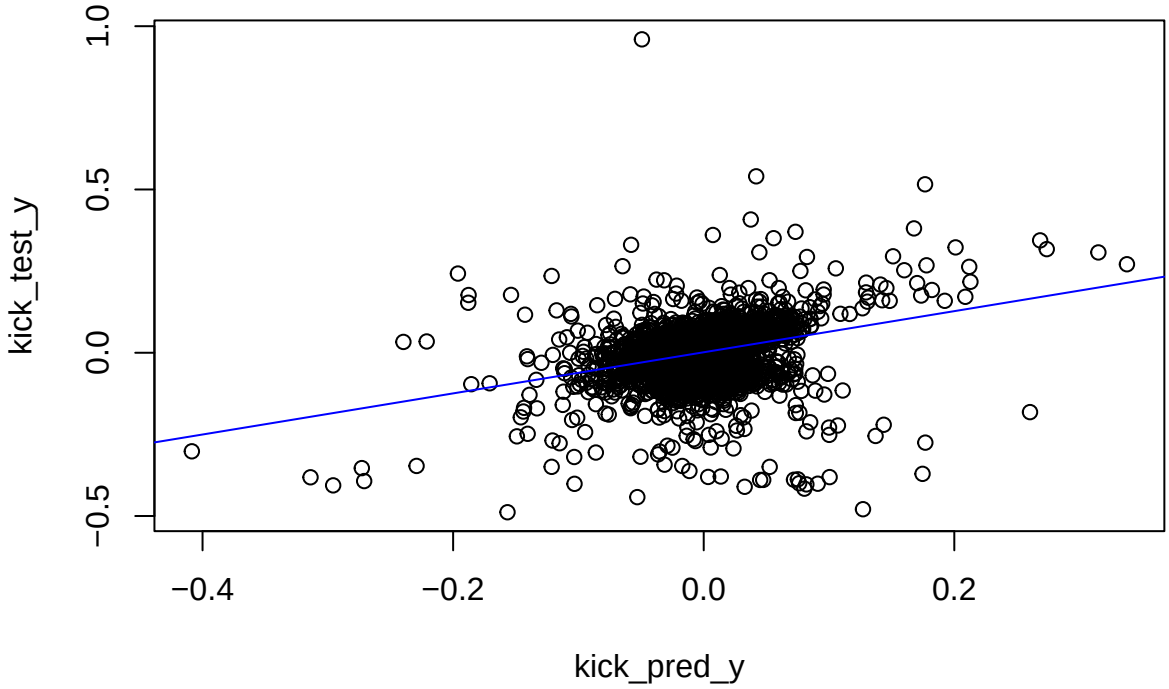

punt_test_y
0.8
0.6
0.4
0.2
0.0
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
punt_pred_y

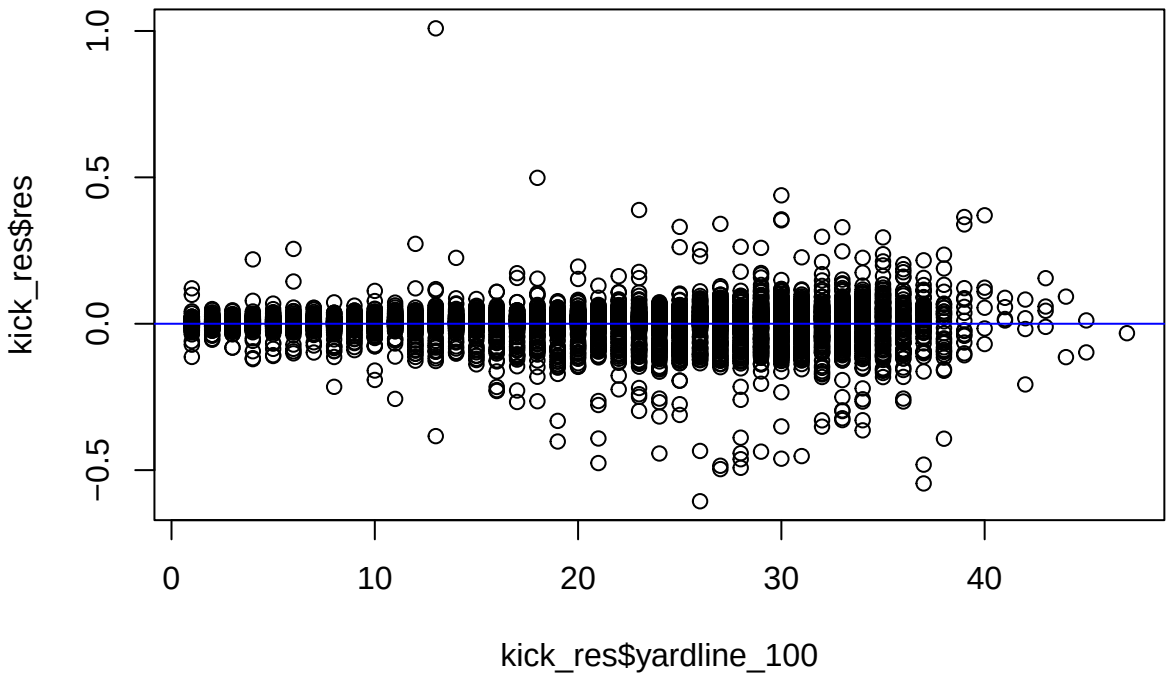


Our optimal punt XG Boost model has a RMSE of 0.0216, which is the lowest RMSE we obtained throughout our XG Boost, Lasso, and Ridge Regression modelling process. Therefore, we will continue with this as our punt WPA model.

Kick Model

```
## [1] "XG Boost RMSE: 0.0594063303865088"
```

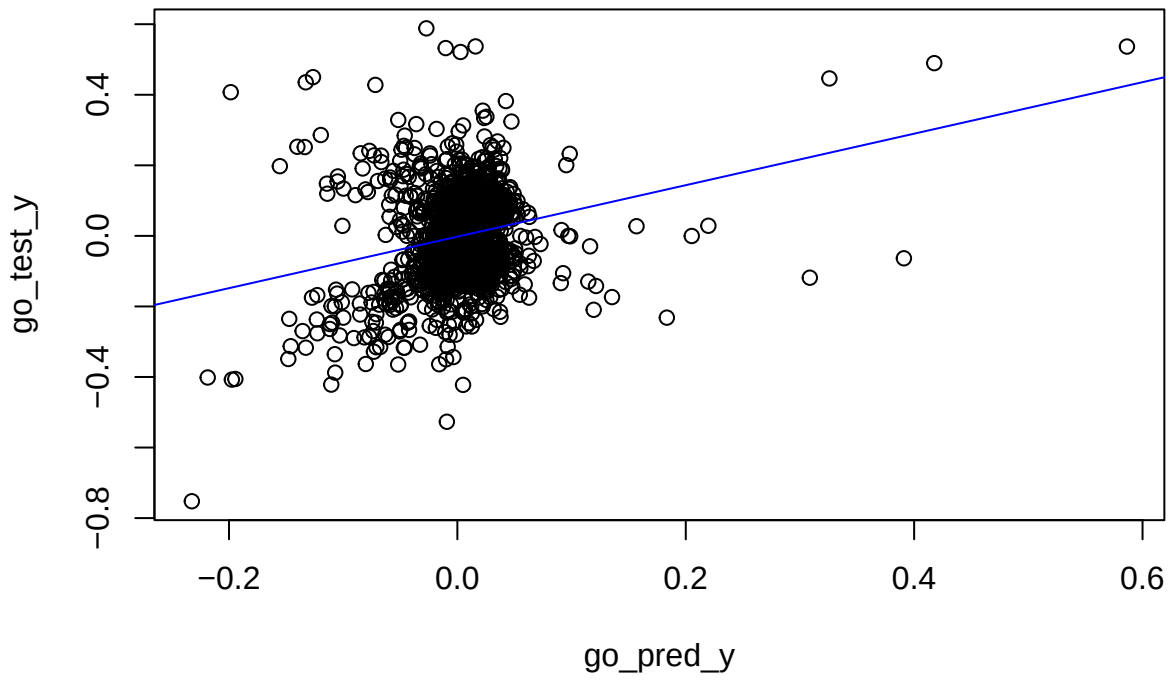

kick_test_y
1.0
0.5
0.0
−0.5
−0.4
−0.2
0.0
0.2
kick_pred_y

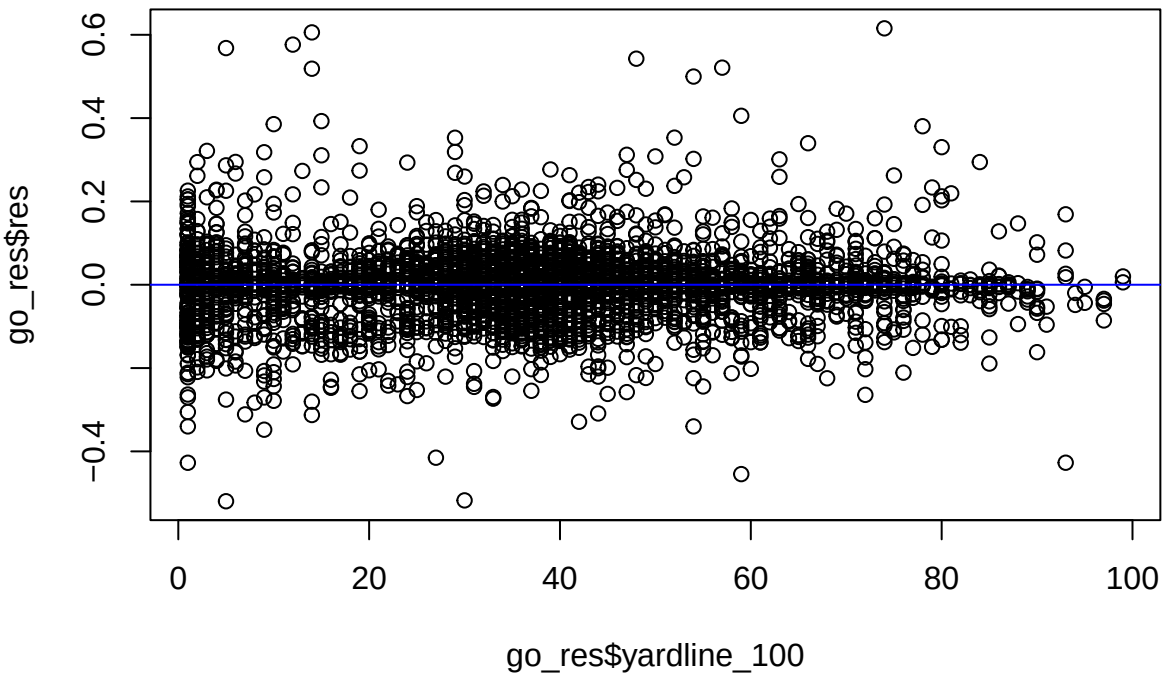


Our optimal kick XG Boost model has a RMSE of 0.3921, which is the lowest RMSE we obtained throughout our XG Boost, Lasso, and Ridge Regression modelling process. Therefore, we will continue with this as our kick WPA model.

Go Model

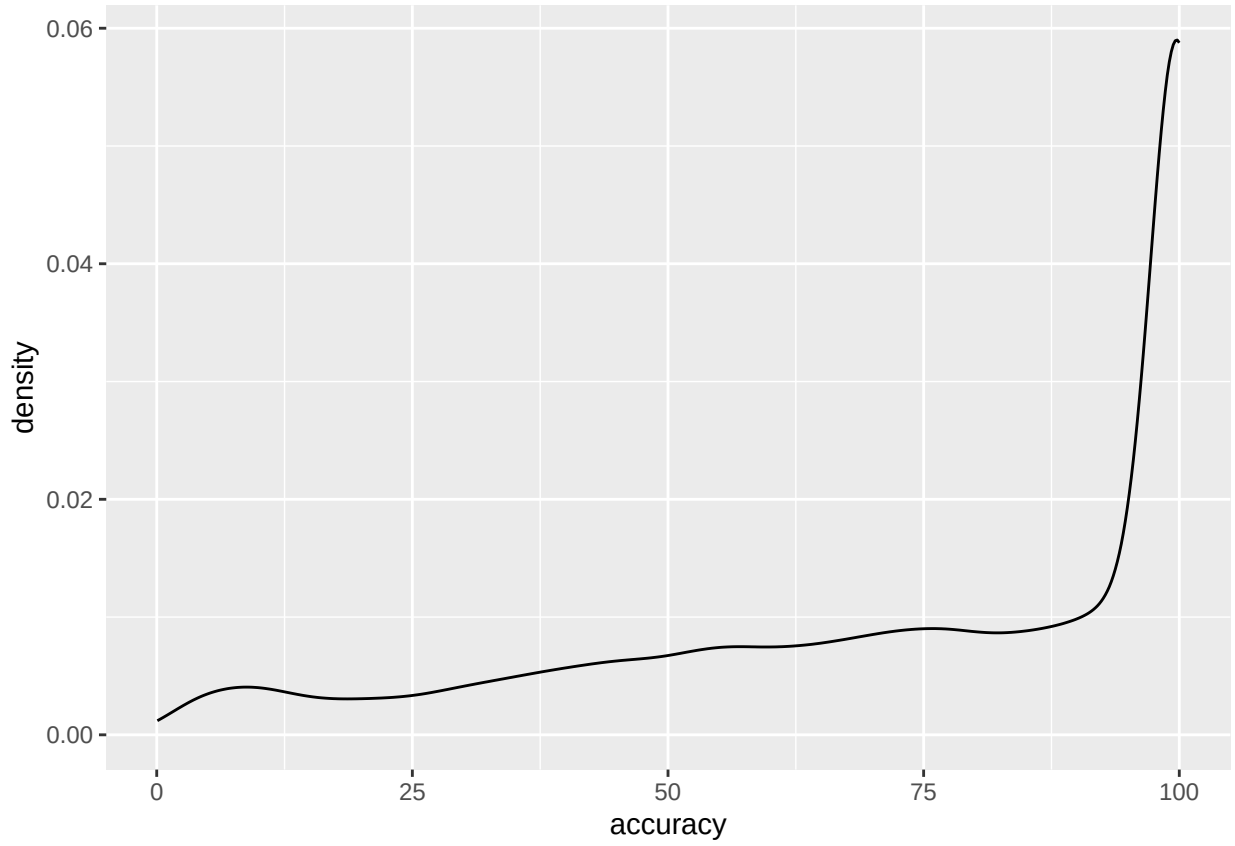
```
## [1] "XG Boost RMSE: 0.0868873248927645"
```

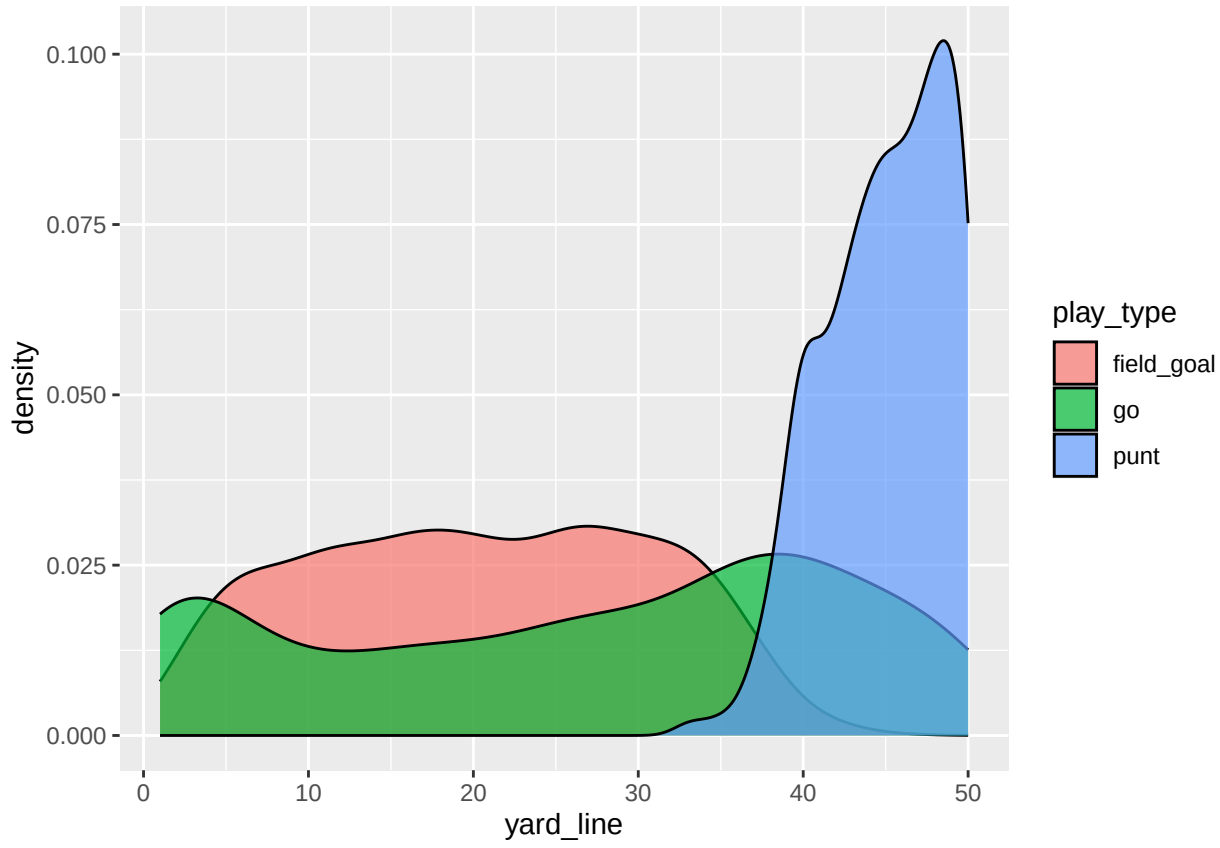

go_test_y
0.4
0.0
−0.4
−0.8
−0.2
0.0
0.2
0.4
0.6
go_pred_y



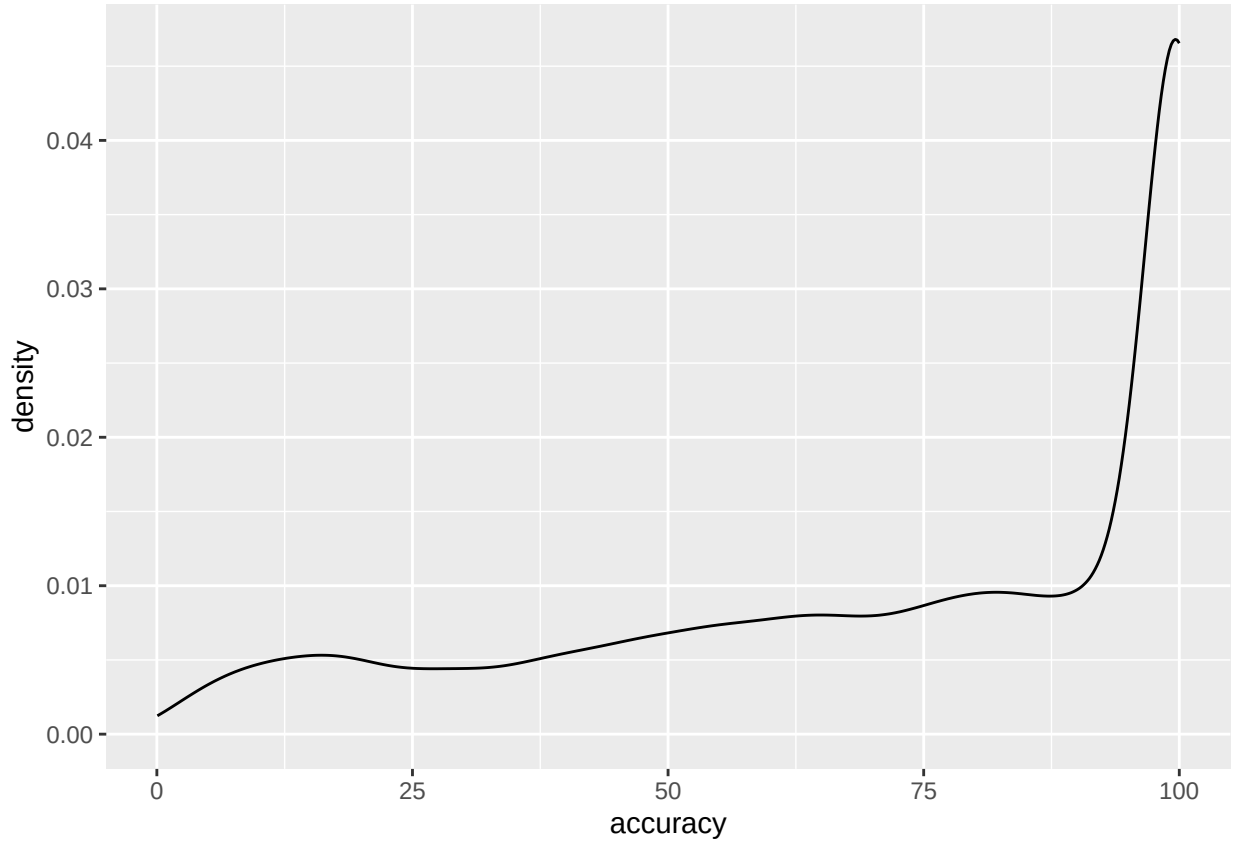
Our optimal go for it XG Boost model has a RMSE of 0.5492, which is the lowest RMSE we obtained throughout our XG Boost, Lasso, and Ridge Regression modelling process. Therefore, we will continue with this as our go for it WPA model.

Results


0.06
0.04
0.02
0.00
density
0
25
50
75
100
accuracy


0.100
0.075
0.050
0.025
0.000
density
0
10
20
30
40
50
yard_line
play_type
field_goal
go
punt

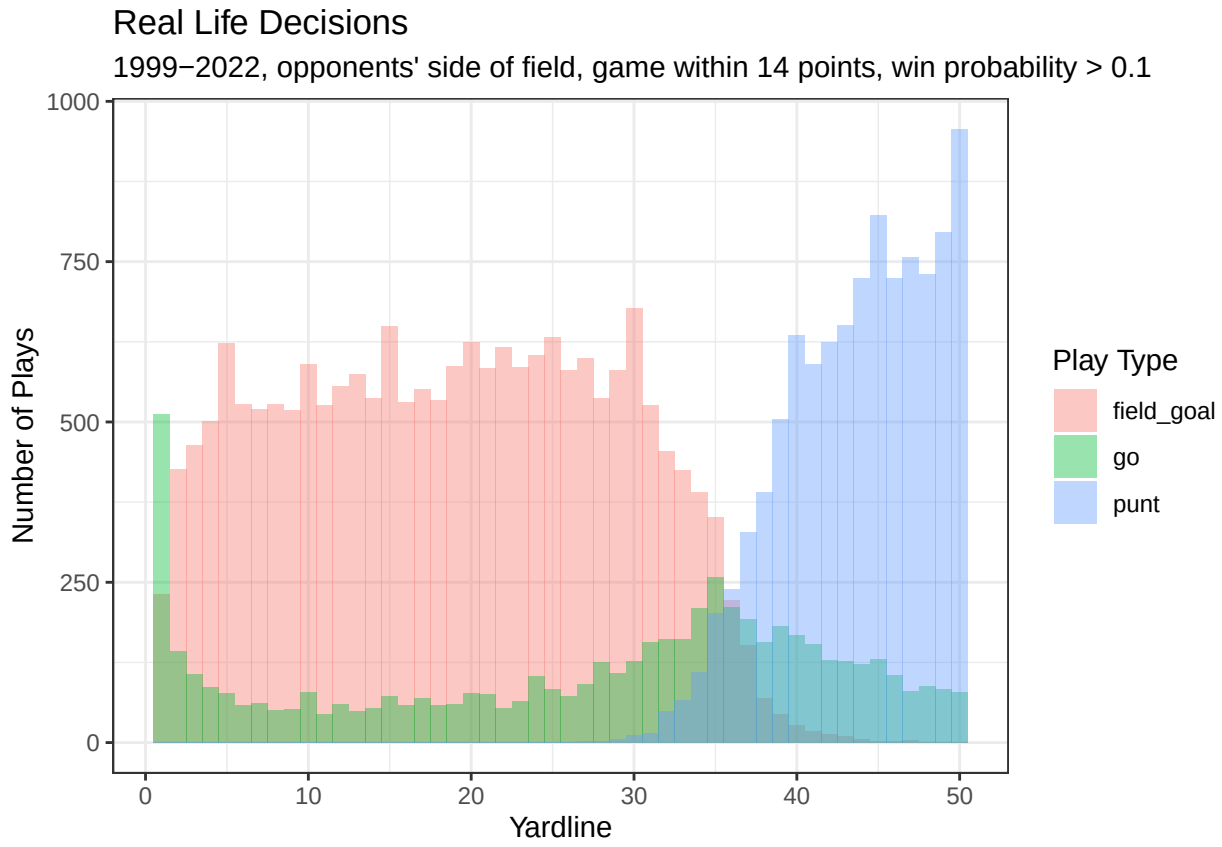

750
500
250
0
count
0
10
20
30
40
50
yard_line
recommendation
field_goal
go
punt

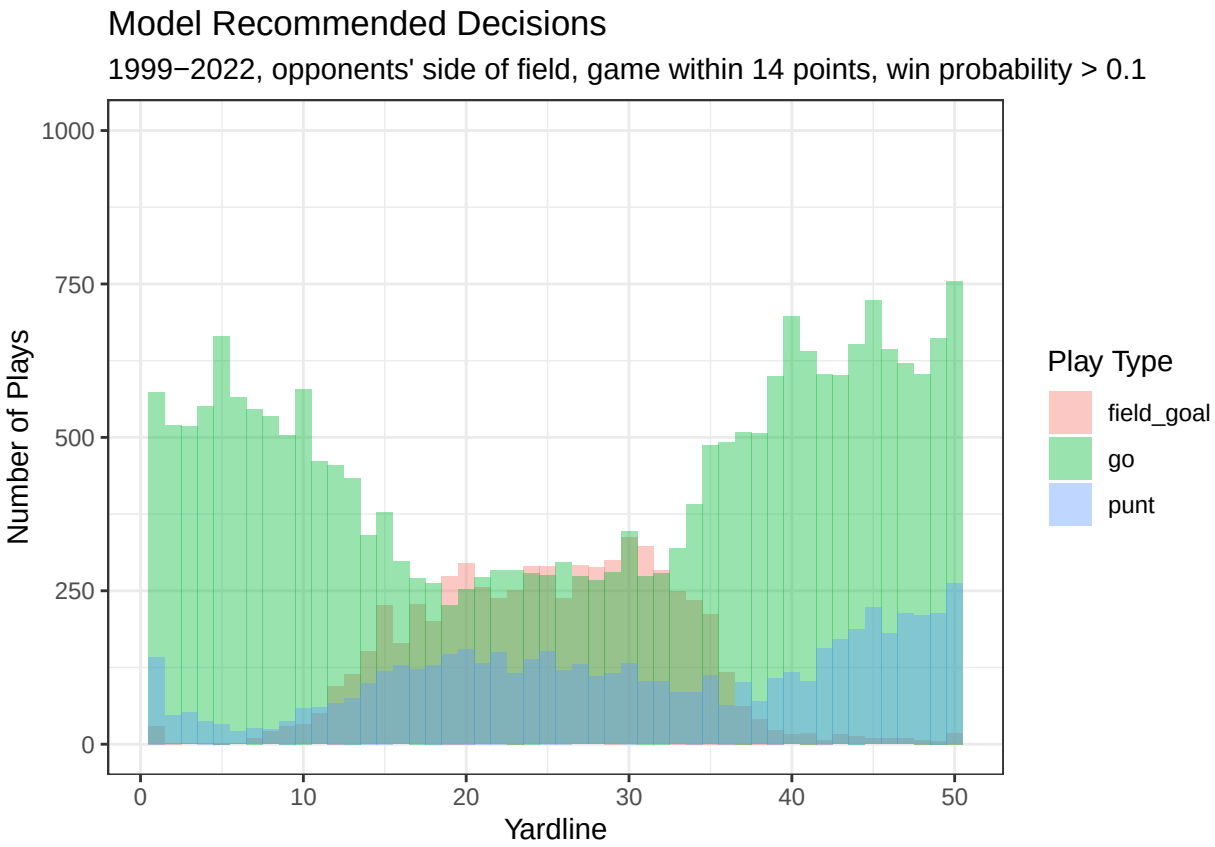



```
##                wpa yardline_100 game_seconds_remaining qtr ydstogo
##     1: -0.002238333           51                   3296   1       1
##     2: -0.019976735            6                   2899   1       3
##     3: -0.018679649           66                   2820   1       1
##     4: -0.095877826           27                   2455   2       4
##     5:  0.030603722           27                   1828   2       5
##    ---
## 46875:  0.028520644           11                   2369   2      10
## 46876: -0.044980898           10                   1819   2      10
## 46877: -0.073177233           29                   1800   3       5
## 46878:  0.060336888           57                    876   4       1
## 46879:  0.002091736           25                    377   4       7
##        score_differential no_score_prob opp_fg_prob opp_safety_prob
##     1:                  0   0.011813287 0.177440062    1.565513e-03
##     2:                  0   0.000751453 0.003594615    5.229356e-05
##     3:                 -3   0.046969537 0.196949929    3.269824e-03
##     4:                 -3   0.027033767 0.055807115    7.228962e-04
##     5:                -10   0.198925869 0.031771343    7.081460e-05
##    ---
## 46875:                  3   0.012635923 0.010552165    1.447756e-04
## 46876:                  6   0.058551728 0.001686924    1.439996e-05
## 46877:                 -9   0.002216538 0.084979071    1.469645e-03
## 46878:                -10   0.084862515 0.183874503    2.234099e-03
## 46879:                 -3   0.078442221 0.041841515    6.270266e-04
##        opp_td_prob   fg_prob  safety_prob      td_prob        wp
##     1: 0.3223033249 0.1836291 9.829091e-03 0.2934196293 0.4737365
```

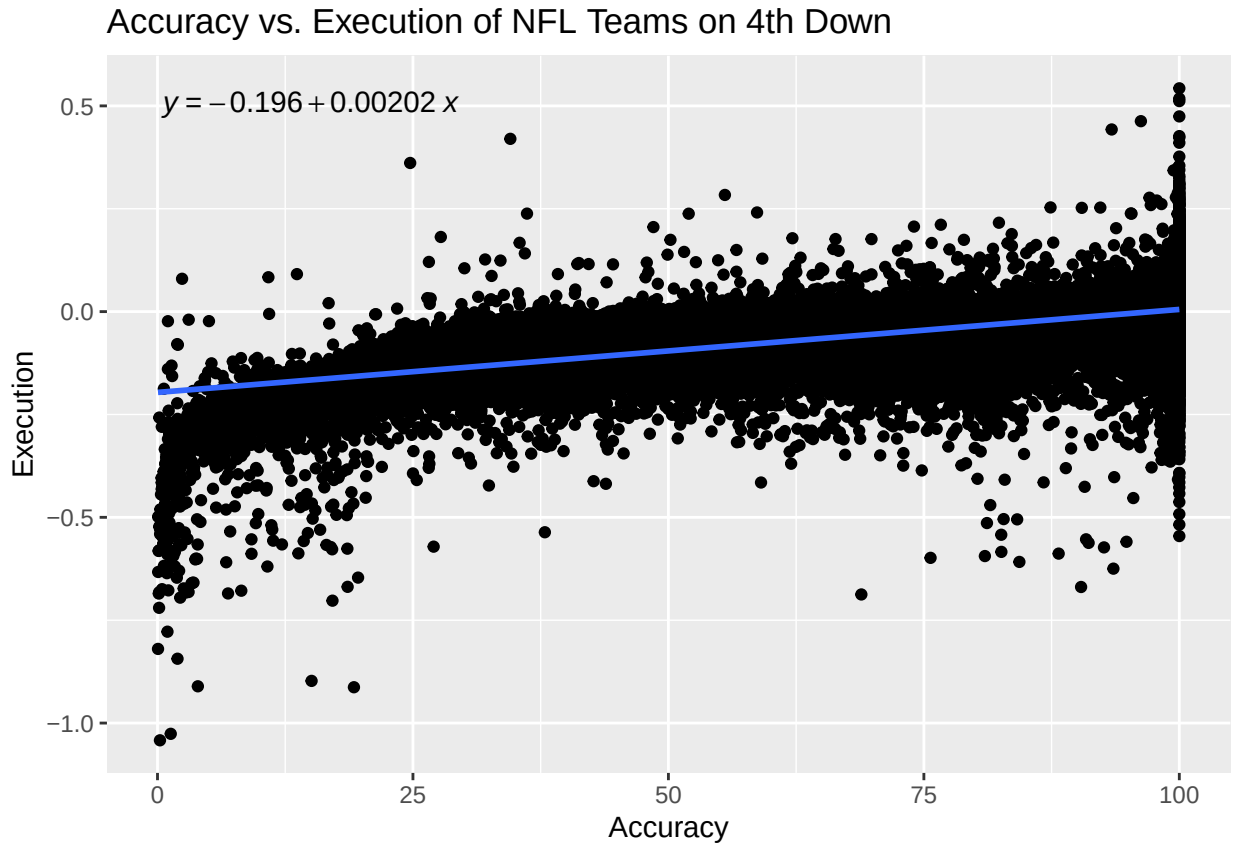
```
##     2: 0.0052889088 0.9839867 4.810112e-05 0.0062778788 0.5815628
##     3: 0.2704848647 0.1542629 3.105036e-03 0.3249579072 0.4060214
##     4: 0.0902073976 0.7886681 3.824418e-04 0.0371782679 0.4443144
##     5: 0.0026942235 0.7643739 1.263318e-04 0.0020374833 0.2256564
##    ---
## 46875: 0.0191436318 0.9411797 3.276049e-04 0.0160162515 0.5929926
## 46876: 0.0005263558 0.9385480 1.056186e-04 0.0005670034 0.7959621
## 46877: 0.1227084289 0.7049640 9.205743e-04 0.0827417670 0.2314794
## 46878: 0.3207639158 0.1546367 6.023312e-03 0.2476048768 0.1292370
## 46879: 0.0705068382 0.7703825 5.302751e-04 0.0376695779 0.4555477
##        posteam_timeouts_remaining defteam_timeouts_remaining  play_type team
##     1:                          2                          3       punt  BAL
##     2:                          2                          3 field_goal  BAL
##     3:                          3                          2       punt  NYJ
##     4:                          3                          2 field_goal  NYJ
##     5:                          2                          0 field_goal  NYJ
##    ---
## 46875:                          3                          3 field_goal   LA
## 46876:                          1                          3 field_goal   LA
## 46877:                          3                          3 field_goal  TEN
## 46878:                          2                          3         go  TEN
## 46879:                          1                          3 field_goal  TEN
##        year     ewpa_punt    ewpa_kick     ewpa_go recommendation correct_call
##     1: 2022 -2.933160e-03 -0.029476417  0.02216806             go           No
##     2: 2022  7.422847e-03 -0.019154117  0.16661067             go           No
##     3: 2022 -1.827045e-02 -0.078910790  0.02621070             go           No
##     4: 2022 -3.410254e-02 -0.066461451  0.01828877             go           No
##     5: 2022  1.498408e-02  0.016281627  0.23541325             go           No
##    ---
## 46875: 1999  9.774473e-03  0.025061386  0.17485692             go           No
## 46876: 1999 -1.629363e-03  0.001786566  0.11933241             go           No
## 46877: 1999  2.587687e-03 -0.054299217  0.01544184             go           No
## 46878: 1999 -3.932085e-05 -0.107563473  0.02578063             go          Yes
## 46879: 1999 -3.640502e-02  0.007501667 -0.01914096     field_goal          Yes
##           ewpa_max    ewpa_play    execution ewpa_max_percentile
##     1: 0.022168064 -0.002933160 -0.024406398           0.5203396
##     2: 0.166610673 -0.019154117 -0.186587408           0.9030483
##     3: 0.026210699 -0.018270450 -0.044890348           0.5979863
##     4: 0.018288767 -0.066461451 -0.114166593           0.4412210
##     5: 0.235413253  0.016281627 -0.204809532           0.9700506
##    ---
## 46875: 0.174856916  0.025061386 -0.146336272           0.9162098
## 46876: 0.119332410  0.001786566 -0.164313309           0.8301798
## 46877: 0.015441844 -0.054299217 -0.088619078           0.3836686
## 46878: 0.025780629  0.025780629  0.034556258           0.5896030
## 46879: 0.007501667  0.007501667 -0.005409932           0.2406621
##        ewpa_play_percentile  accuracy
##     1:          0.101452676  58.11131
##     2:          0.019966296  11.69180
##     3:          0.021864801  42.38785
##     4:          0.001471874  56.02509
##     5:          0.400093859  43.00433
##    ---
## 46875:          0.578254656  66.20448
```

```
## 46876:          0.154056187  32.38764
## 46877:          0.002495787  61.88272
## 46878:          0.589603021 100.00000
## 46879:          0.240662130 100.00000
```

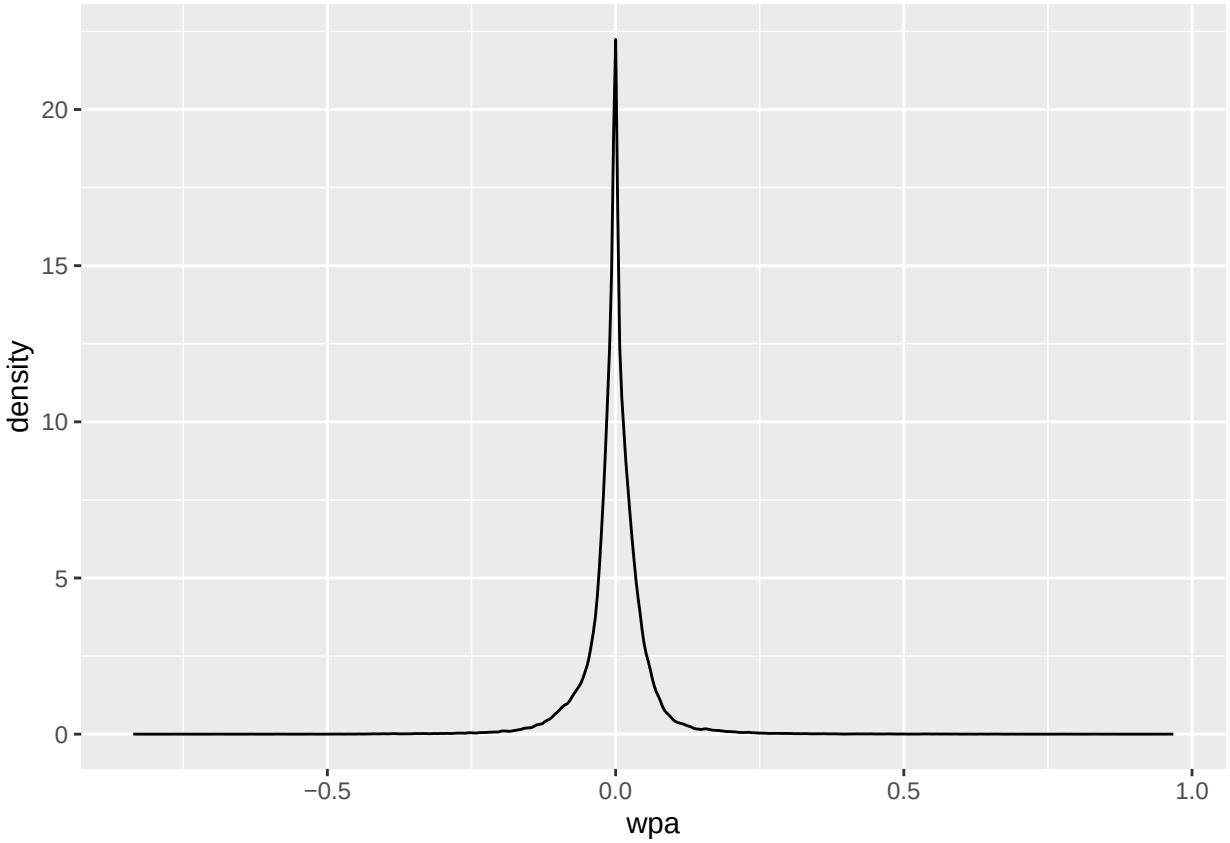


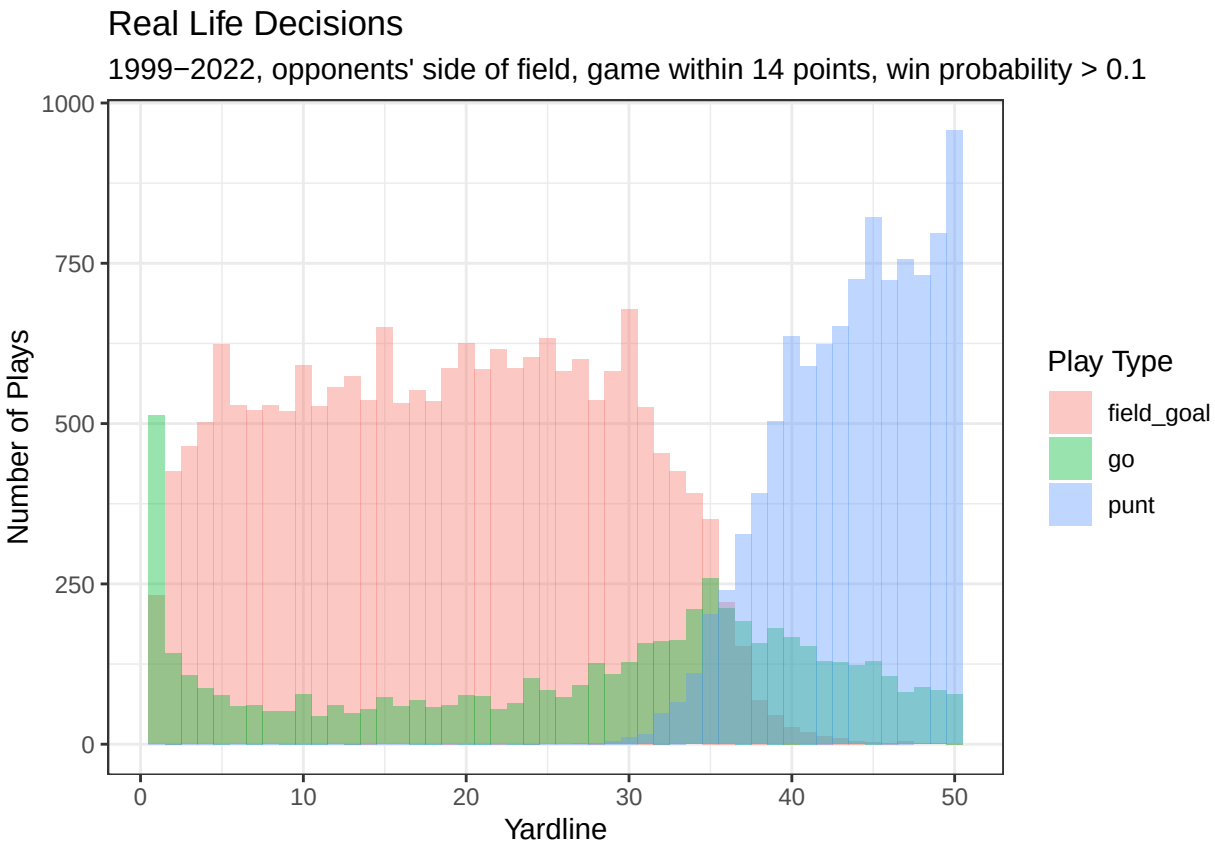


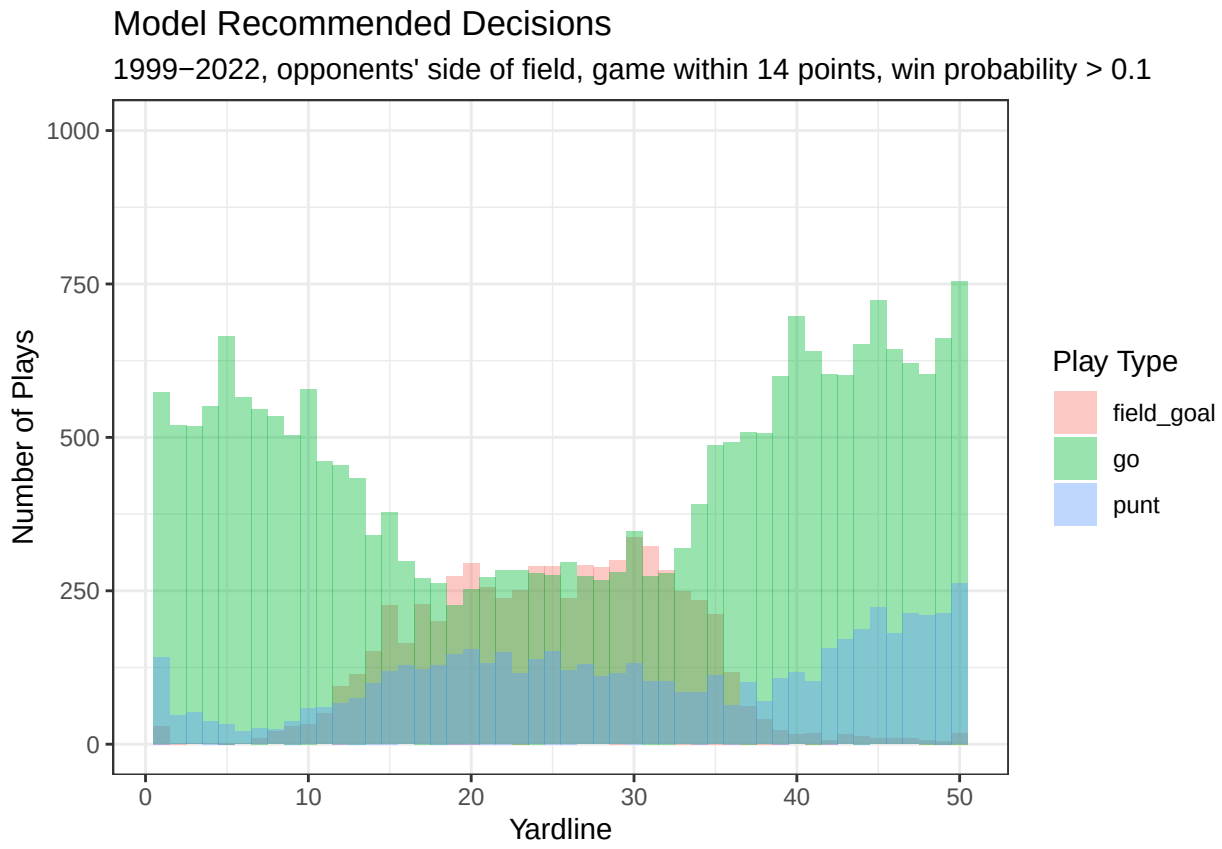
	field_goal	go	punt
field_goal	5879	10932	2515
go	389	5033	1059
punt	891	16673	3508



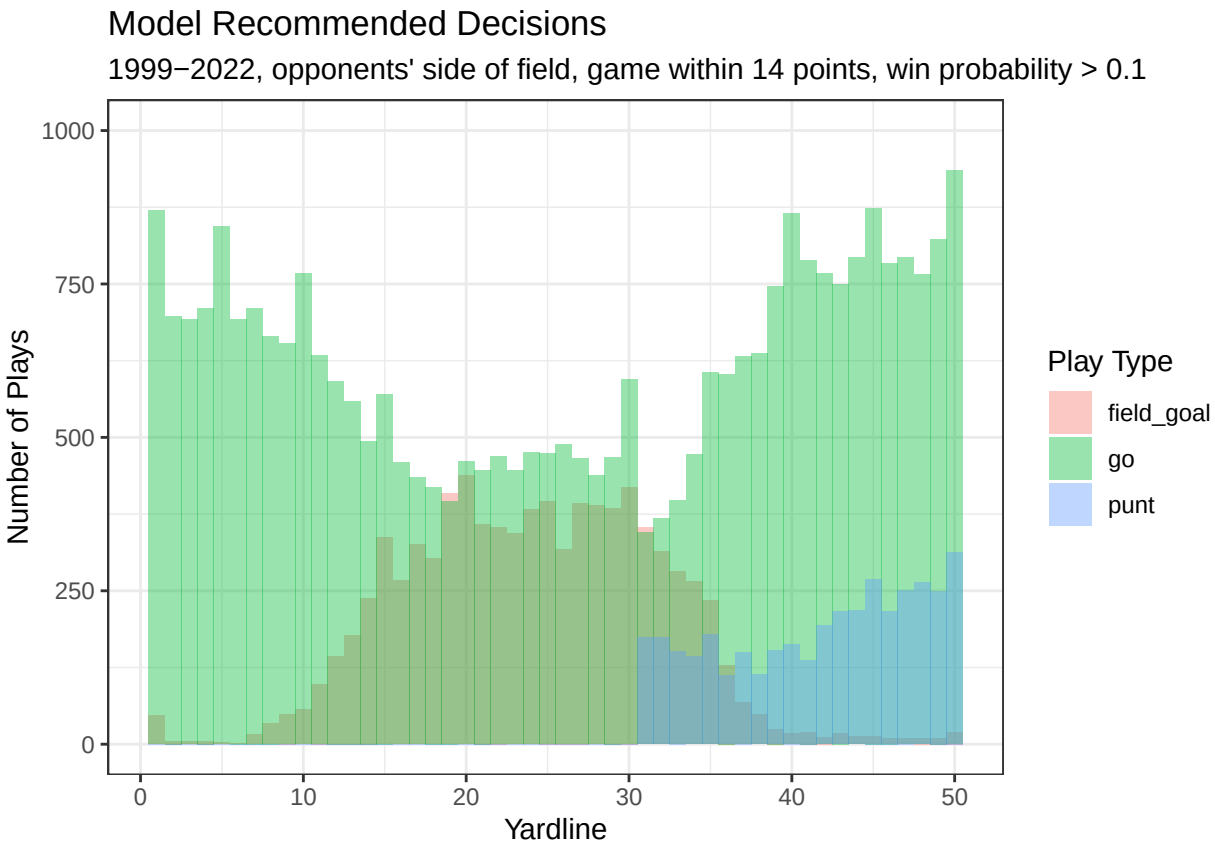
ewpa_punt	ewpa_kick	ewpa_go	recommendation	play_type	wpa	execution	accuracy
-0.120	-0.203	-0.010	go	go	0.532	0.543	100.000
0.011	-0.101	-0.003	punt	punt	0.529	0.518	100.000
-0.092	-0.273	-0.038	go	go	0.474	0.512	100.000
-0.115	-0.288	0.007	go	go	0.481	0.474	100.000
-0.013	-0.338	-0.126	punt	go	0.450	0.463	96.239
-0.007	-0.471	-0.133	punt	go	0.435	0.443	93.381
-0.015	-0.251	0.130	go	go	0.556	0.427	100.000
-0.070	-0.360	-0.005	go	go	0.418	0.423	100.000
0.101	-0.243	0.003	punt	go	0.521	0.420	34.531
-0.128	-0.277	0.064	go	go	0.474	0.410	100.000

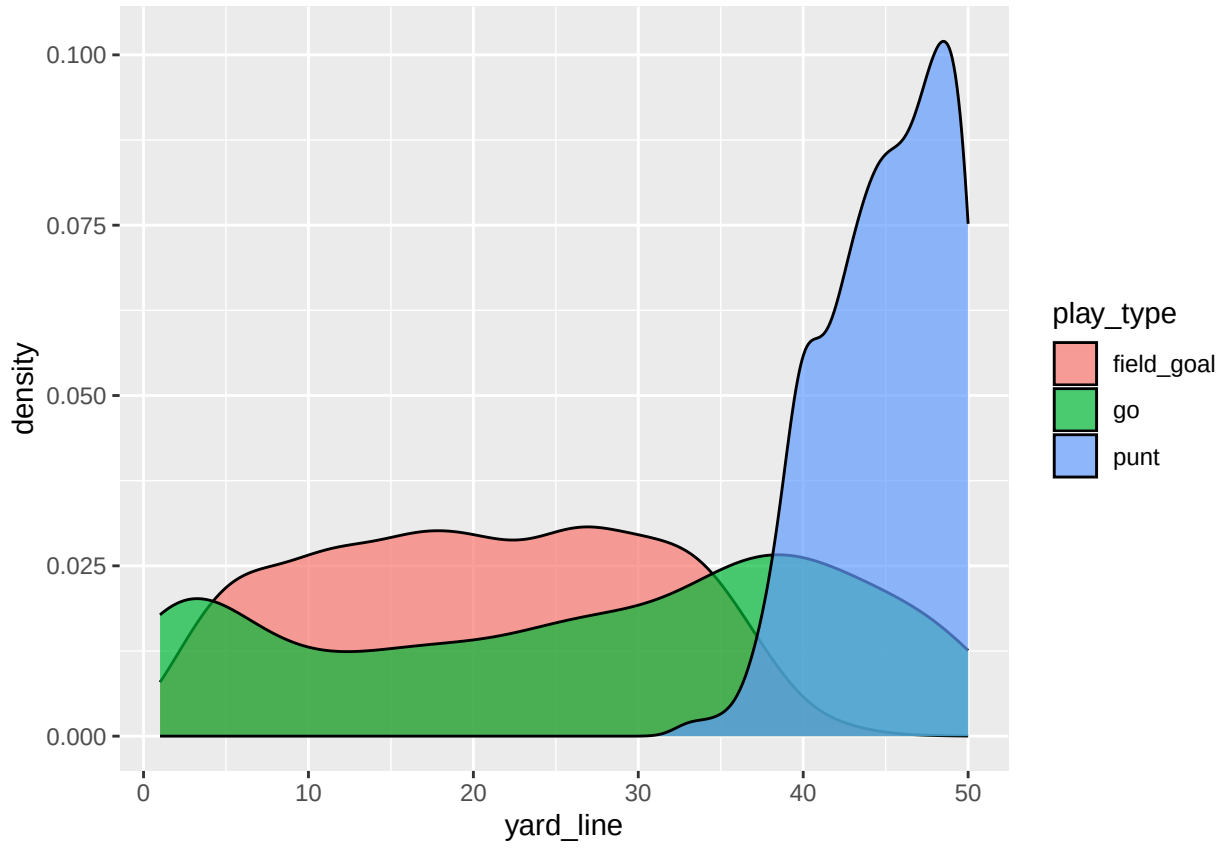

density
20
15
10
5
0
−0.5
0.0
0.5
1.0
wpa


Real Life Decisions
1999−2022, opponents' side of field, game within 14 points, win probability > 0.1
Number of Plays
1000
750
500
250
0
0
10
20
30
40
50
Yardline
Play Type
field_goal
go
punt




```
## # A tibble: 224 x 3
## # Groups:   yard_line [99]
##    yard_line play_type count
##        <dbl> <fct>     <int>
##  1       -49 go          145
##  2       -49 punt        979
##  3       -48 go          127
##  4       -48 punt       1021
##  5       -47 go          116
##  6       -47 punt        964
##  7       -46 go          146
##  8       -46 punt       1076
##  9       -45 go          167
## 10       -45 punt       1306
## # ... with 214 more rows
```


Model Recommended Decisions
1999−2022, opponents' side of field, game within 14 points, win probability > 0.1
Number of Plays
1000
750
500
250
0
0
10
20
30
40
50
Yardline
Play Type
field_goal
go
punt


0.100
0.075
0.050
0.025
0.000
density
0
10
20
30
40
50
yard_line
play_type
field_goal
go
punt

Discussion and Conclusion

While our