

# Variable Importance in Secondary Pitch Design

A Machine Learning Baseball Analysis

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# Whiffs & Chases

- The purpose of this project is to take secondary pitches thrown after fastballs and build statistical models that predict how a pitcher can get whiffs and chases.
- The predictive variables used are then ranked in terms of their importance in predicting the outcome, which gives an idea on how important it actually is for a pitcher to focus on.
- Four of the ten variables used have to do with comparing the secondary pitch to the fastball just thrown
- The idea then is that a pitcher who wants to fine-tune a secondary pitch or add one to his arsenal to fix his lack of whiffs or chases can wisely prioritize which targets he wants to focus on most during pitch development while keeping his fastball intact.

# The Variables

- Vertical Strike Zone Location
- Horizontal Strike Zone Location
- Vertical Strike Zone Location of Previous Fastball
- Horizontal Strike Zone Location of Previous Fastball
- Pitch Speed
- Speed Difference
- Spin Rate
- Horizontal Break
- Vertical Break
- Break to Tunnel Ratio

# Break to Tunnel Ratio

- This stat shows the ratio of post-tunnel break to the distance of back to back pitches at the Tunnel Point (23 feet 8 inches in front of home plate). The idea here is that having a large ratio between pitches means that the pitches are either tightly clustered at the hitter's decision-making point or the pitches are separating a lot after the hitter has selected a location to swing at. Either way a pitcher's ratio can be large (Sayre).
- 124 models were built: 62 dealing with whiff outcomes, 62 dealing with chase outcomes. For all models, the location was the most important determinant.
- In 77.42% of the whiff models and 48.39% of chase models, Break to Tunnel Ratio is the next most important variable

# Model Methodology

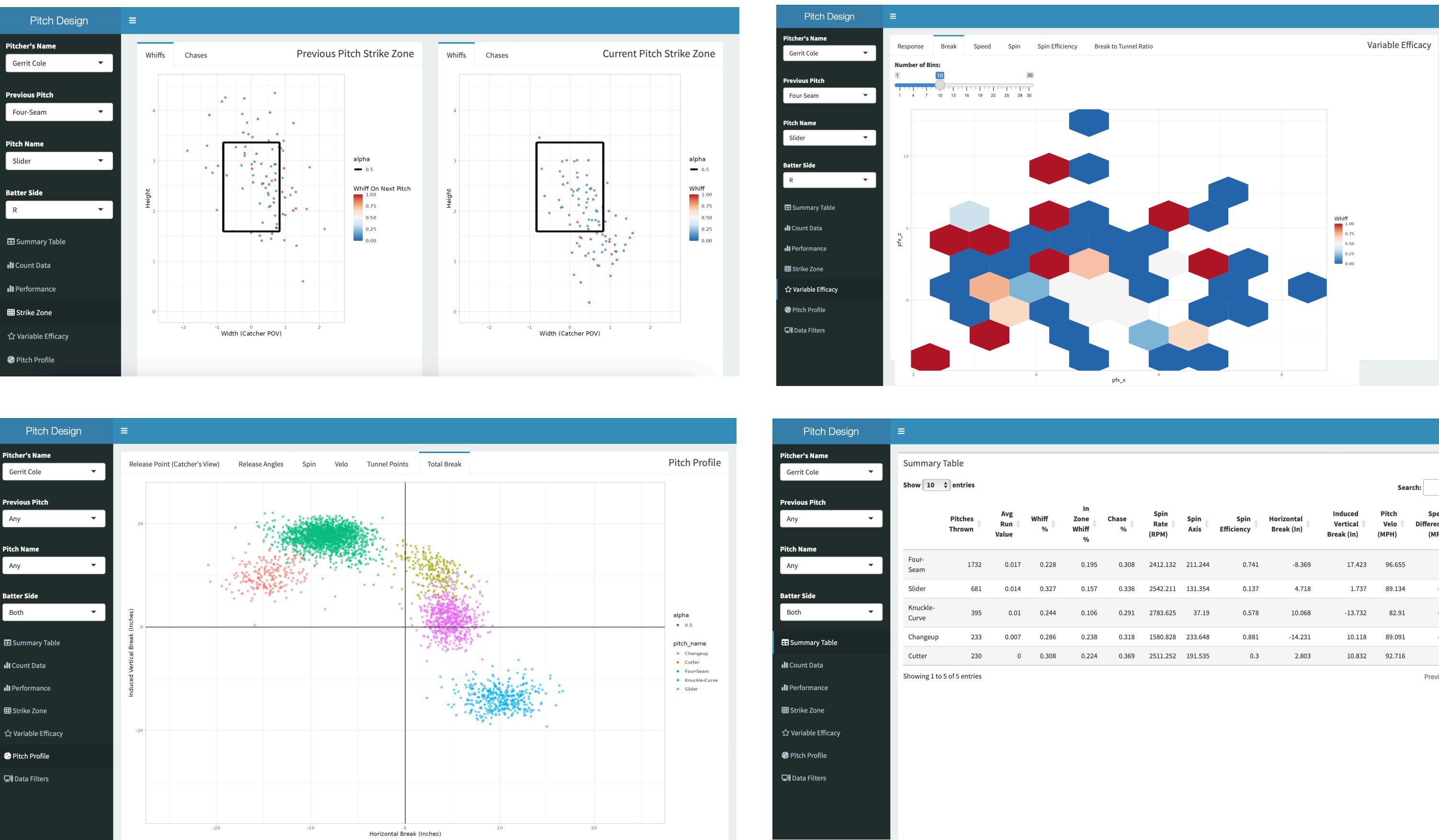
- Download all Statcast pitch data from 2015 to 2023 (excluding 2020 shortened season due to unreliability)
- Run all wrangling and model code in R
- Gather all secondary pitches (Curveballs, Sliders, Changeups, Sweepers, Splitters, Knuckle Curves, Slurves) thrown after a fastball (Four-Seamers, Sinkers, Cutters)
- Use physics and trigonometry to calculate the pitch difference variables (HUGE help from <http://baseball.physics.illinois.edu/>)
- Split up data by pitcher handedness, batter handedness, fastball, secondary pitch
- Downsample the majority class of the response variable (whiff, chase for a 50/50 split of pitches that were and were not those outcomes
- Split the downsampled data into a 70/30 training/testing sample split
- Run training data through **EXTREME GRADIENT BOOSTING** (with 500 decision trees) to predict the outcome of the pitch
- On testing data, use the model to compare the predicted outcomes to the real outcomes and measure the testing accuracy If accuracy is sufficient, run a variable importance graph to measure each variable's impact
- To see the code I wrote to do all this: <https://github.com/djt-5/Baseball-Analytics>
- .

# Shiny App

Knowing the importance of each variable is great, but more information is needed. A pitcher needs to see the quantities within those variables he should strive for to improve his outcomes. To help with that process, use the ShinyApp I developed.

The app includes a

- Summary of each pitch type
- A look at the quantities and successes of the pitch by balls and strikes
- How each pitch does in whiffs and chases, by its previous pitch type thrown
- Release and pitch movement visuals
- A visual of the strike zone showing the best spots to throw
- Interactive graphs there to find the most successful quantities of tunnel and break variables
- A whole page to apply filters to the data to narrow down the best pitch shape



[https://danielthom18.shinyapps.io/mlb\\_pitch\\_development\\_app/](https://danielthom18.shinyapps.io/mlb_pitch_development_app/)

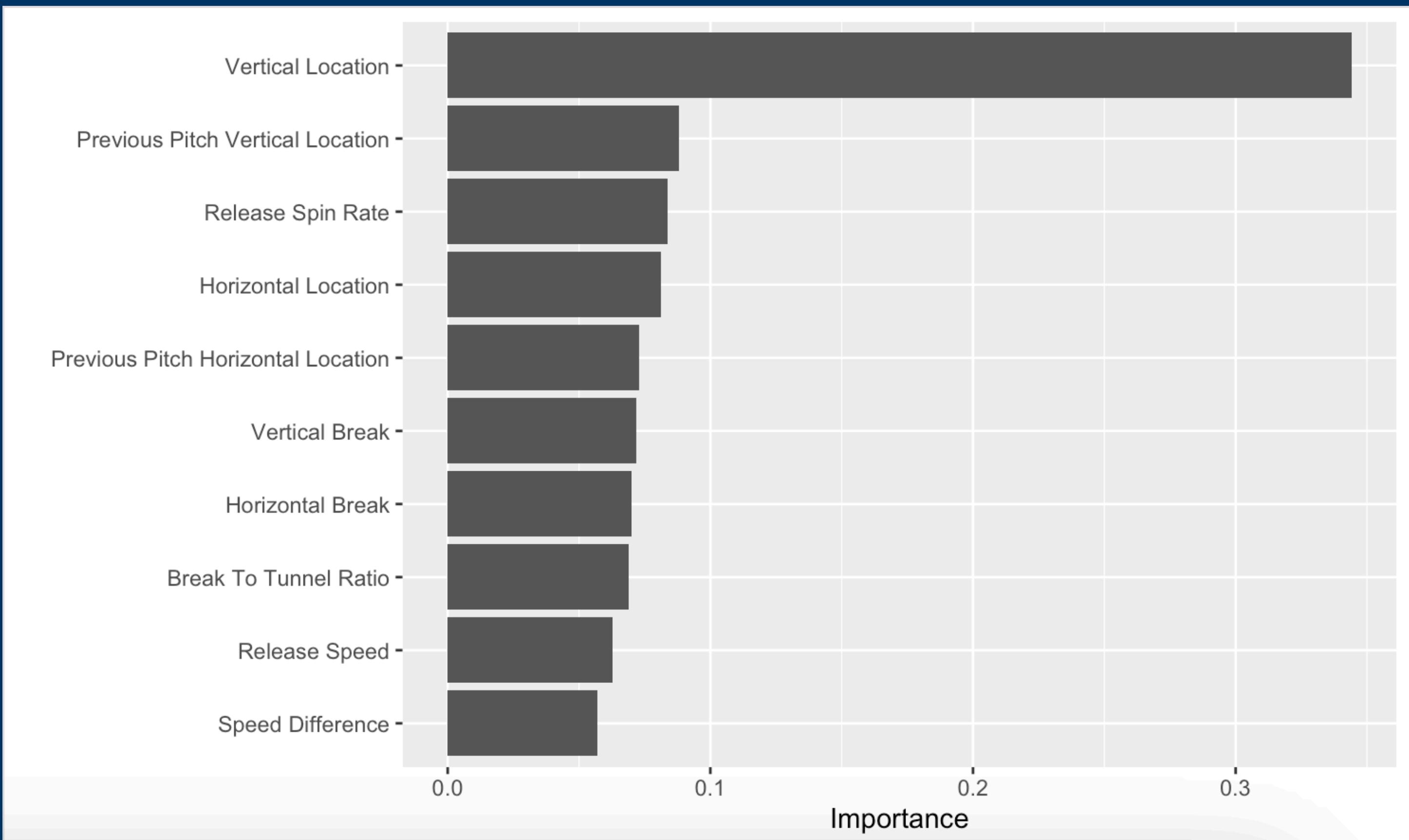
# Right Handed Pitchers vs Right Handed Hitters

# Cutter -> Changeup | RHP -> RHH | Whiff

**Training Sample: n = 1172 pitches**

**Testing Sample: n = 504 pitches**

**Testing Accuracy: 66.87%**

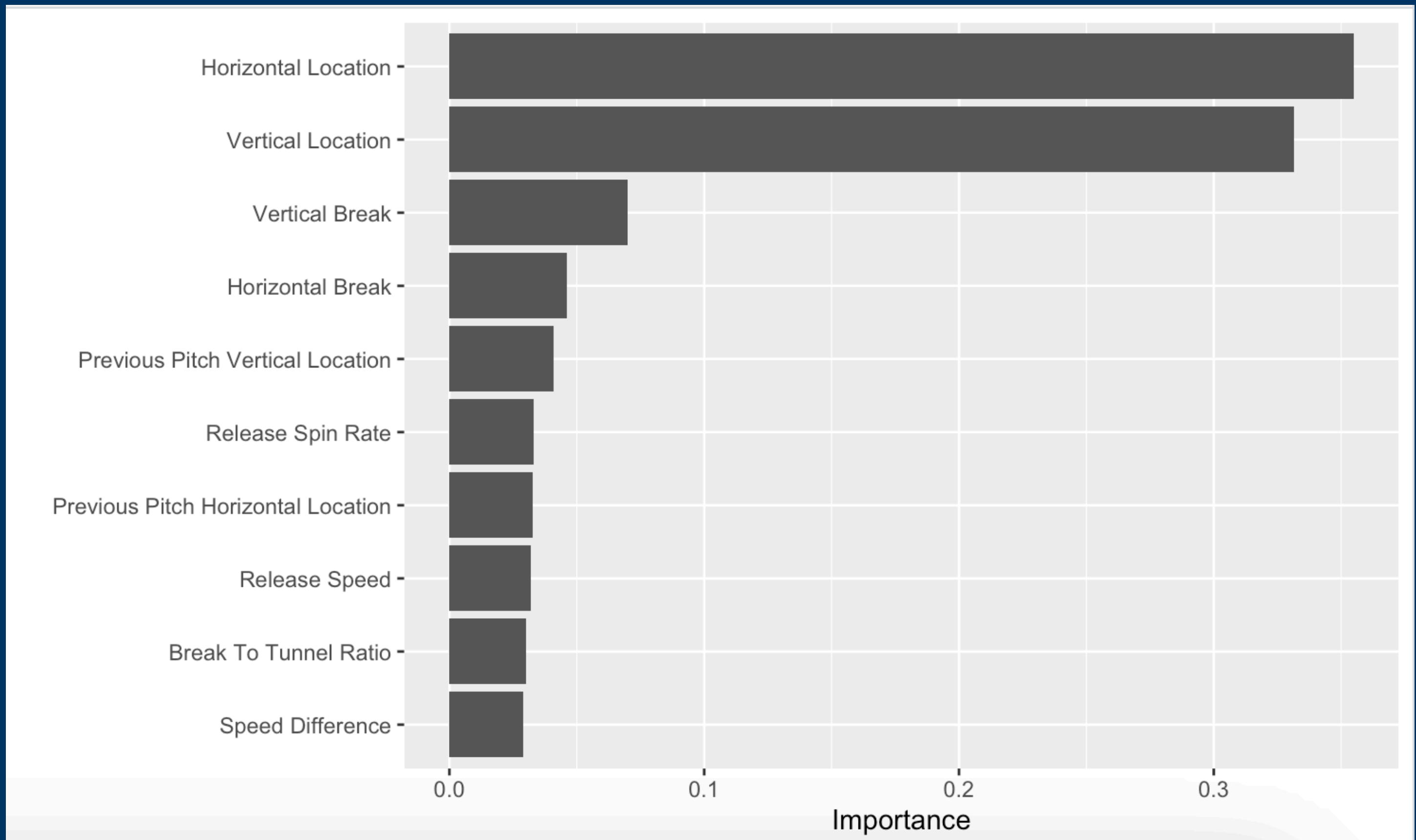


# Cutter -> Changeup | RHP -> RHH | Chase

**Training Sample: n = 1624 pitches**

**Testing Sample: n = 698 pitches**

**Testing Accuracy: 72.49%**

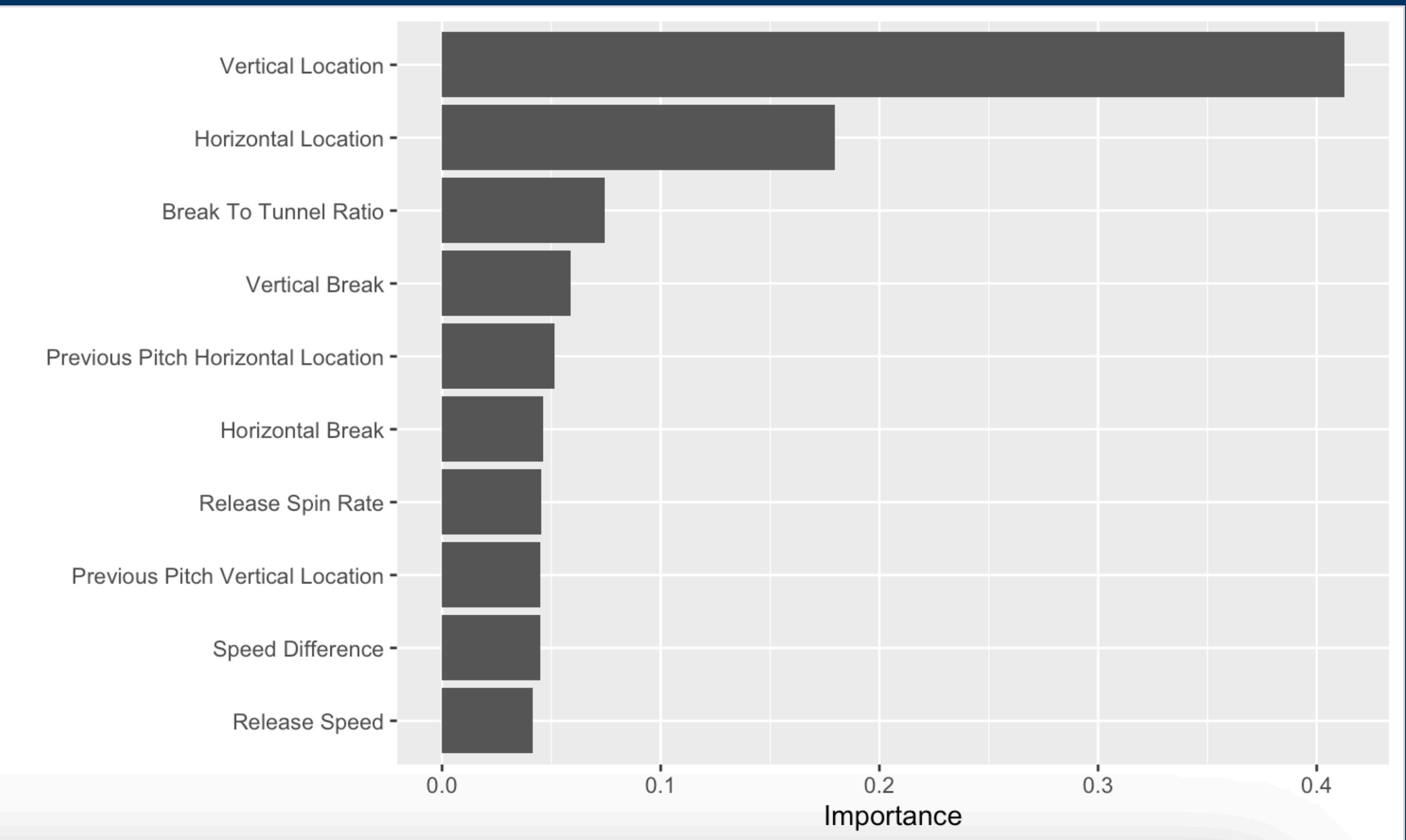


# Cutter -> Curveball | RHP -> RHH | Whiff

**Training Sample: n = 1696 pitches**

**Testing Sample: n = 728 pitches**

**Testing Accuracy: 74.04%**

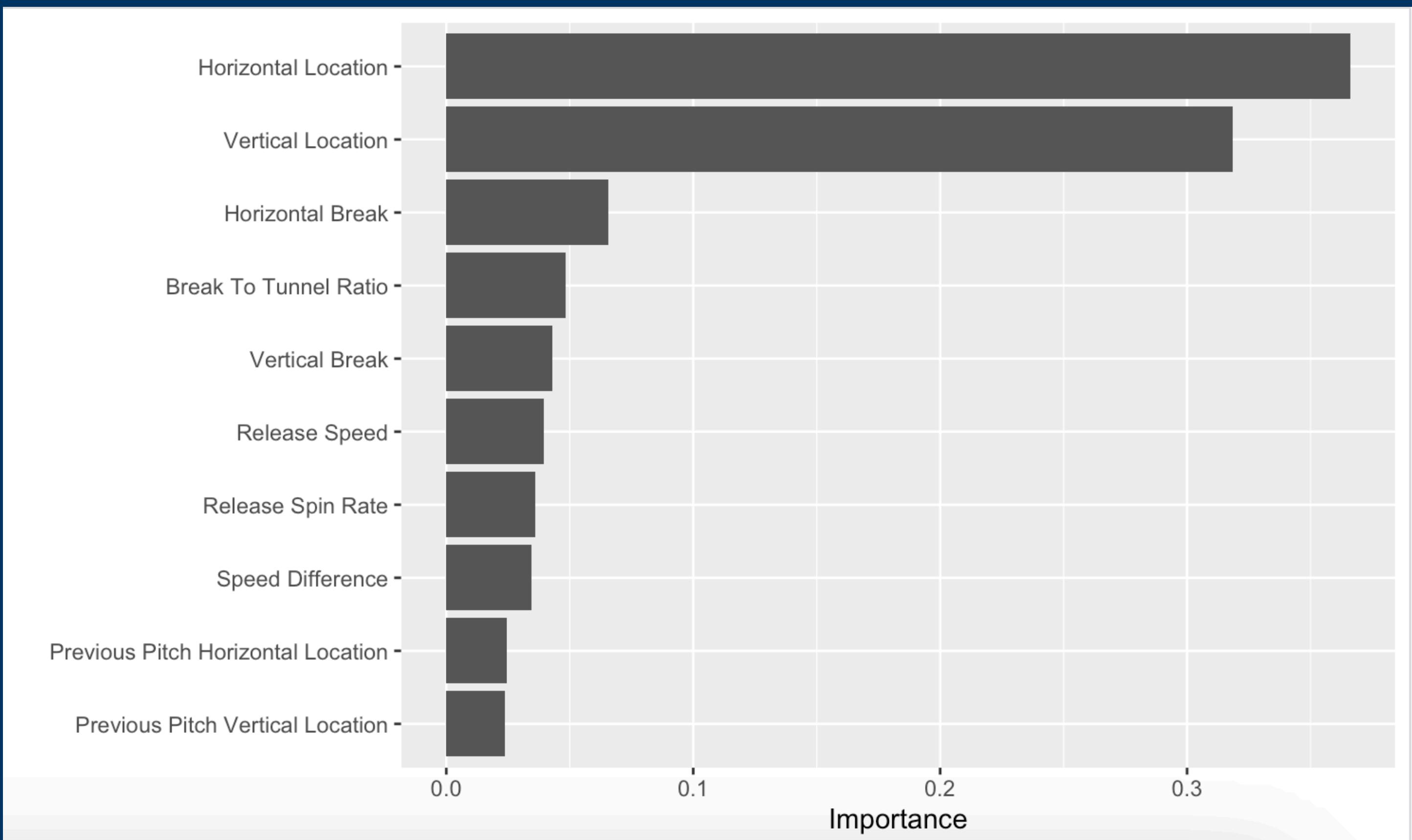


# Cutter -> Curveball | RHP -> RHH | Chase

**Training Sample: n = 2380 pitches**

**Testing Sample: n = 1022 pitches**

**Testing Accuracy: 70.94%**

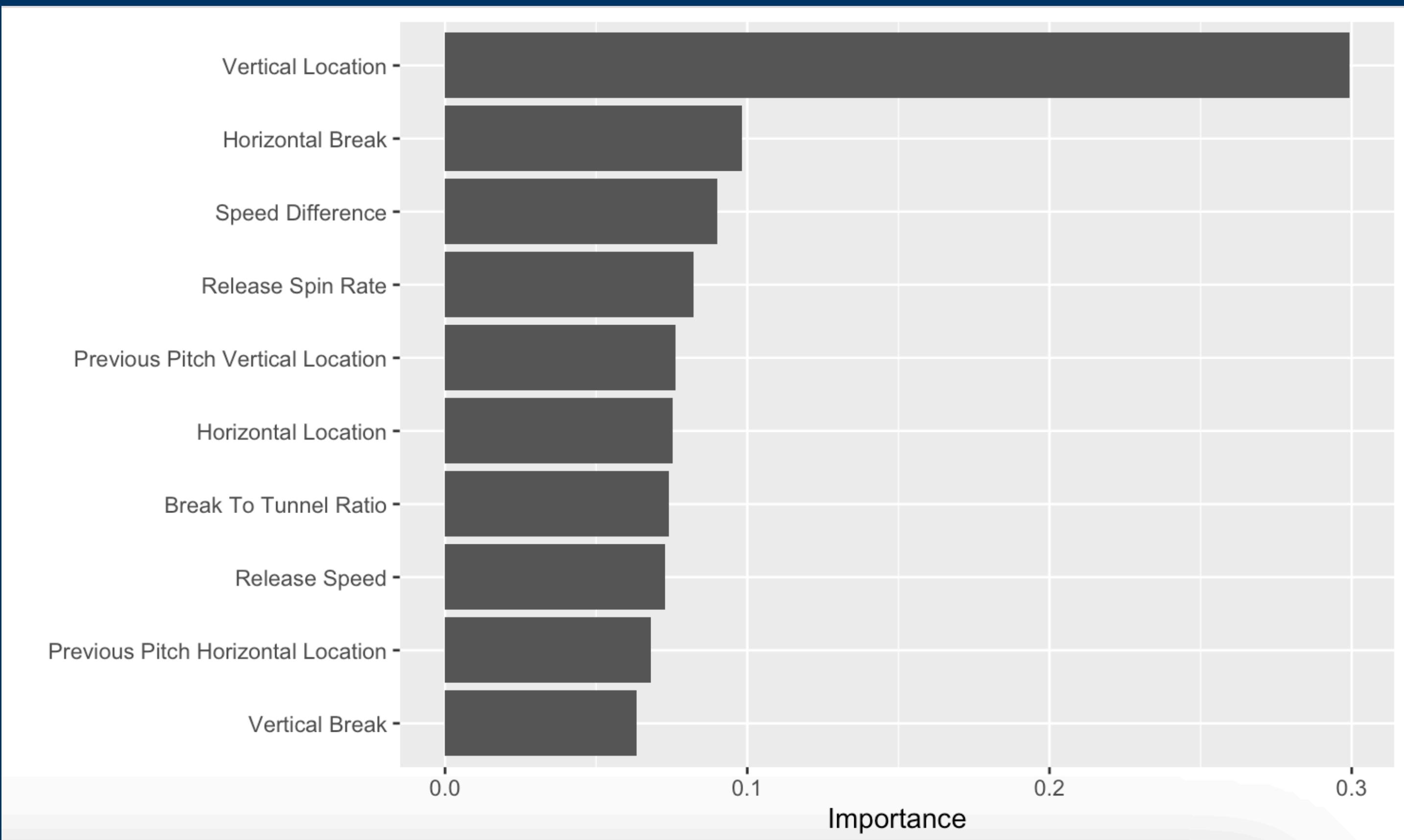


# Cutter -> Splitter | RHP -> RHH | Whiff

**Training Sample: n = 400 pitches**

**Testing Sample: n = 172 pitches**

**Testing Accuracy: 72.09%**

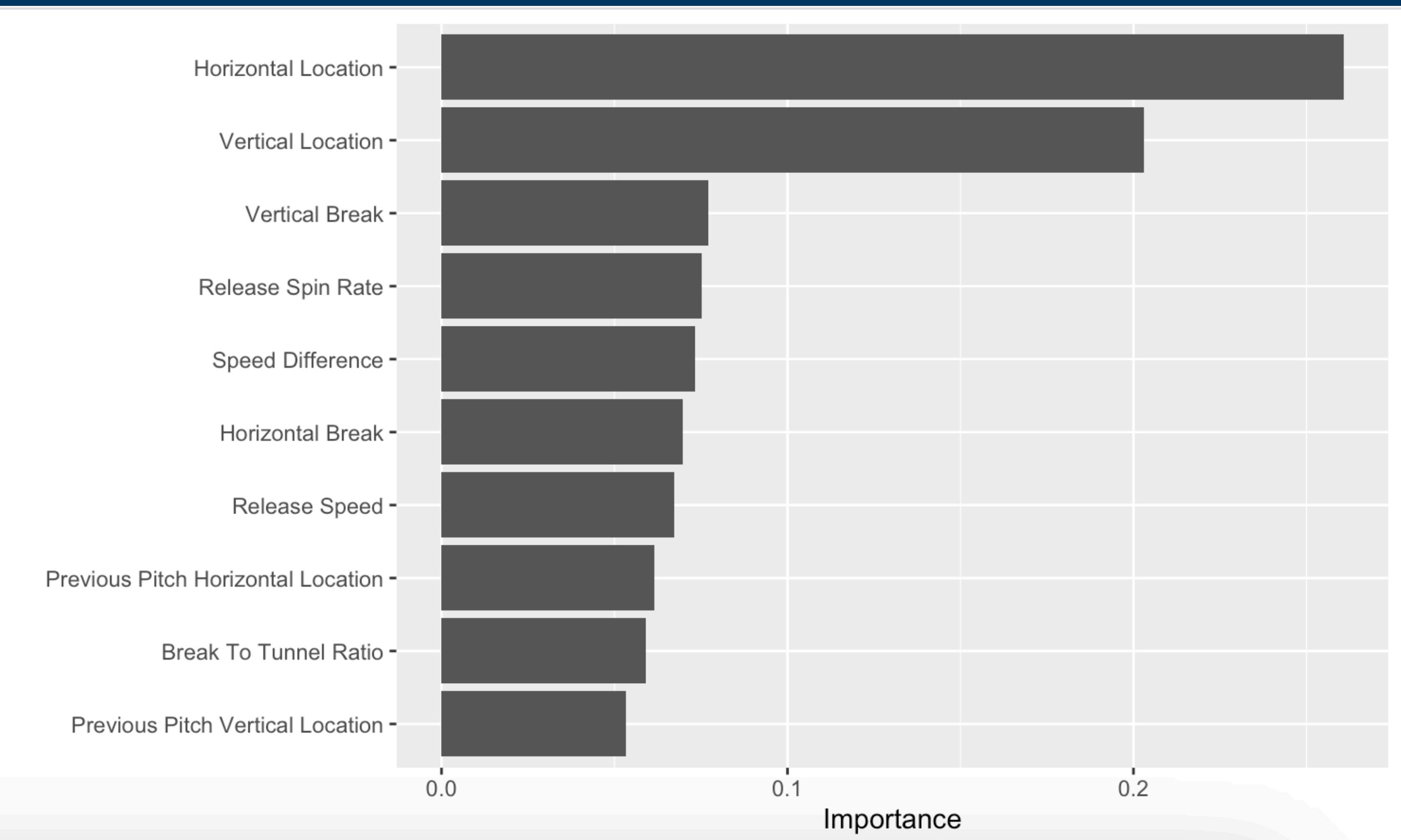


# Cutter -> Splitter | RHP -> RHH | Chase

**Training Sample: n = 472 pitches**

**Testing Sample: n = 204 pitches**

**Testing Accuracy: 74.51%**

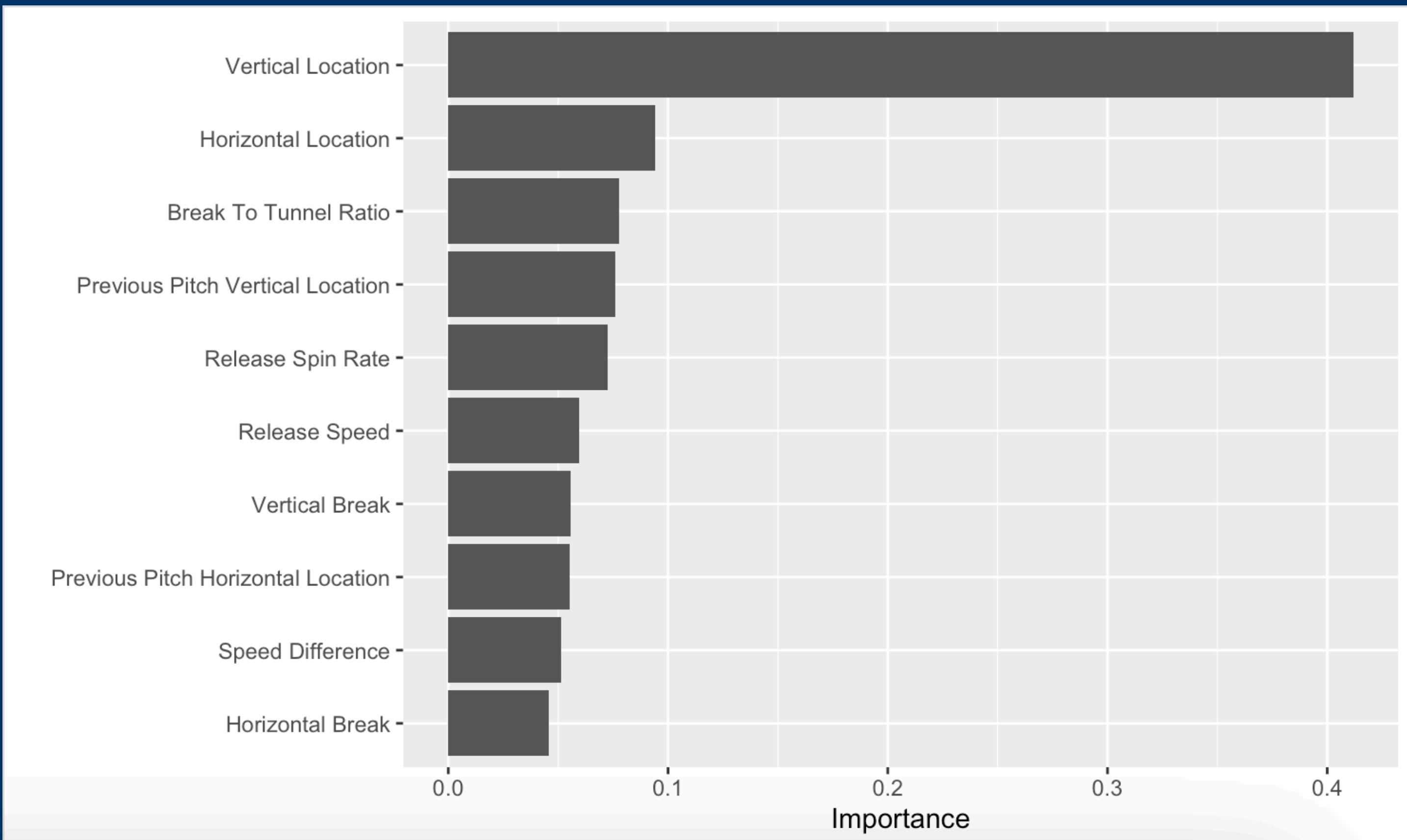


# Cutter -> Knuckle Curve | RHP -> RHH | Whiff

**Training Sample: n = 638 pitches**

**Testing Sample: n = 274 pitches**

**Testing Accuracy: 75.18%**

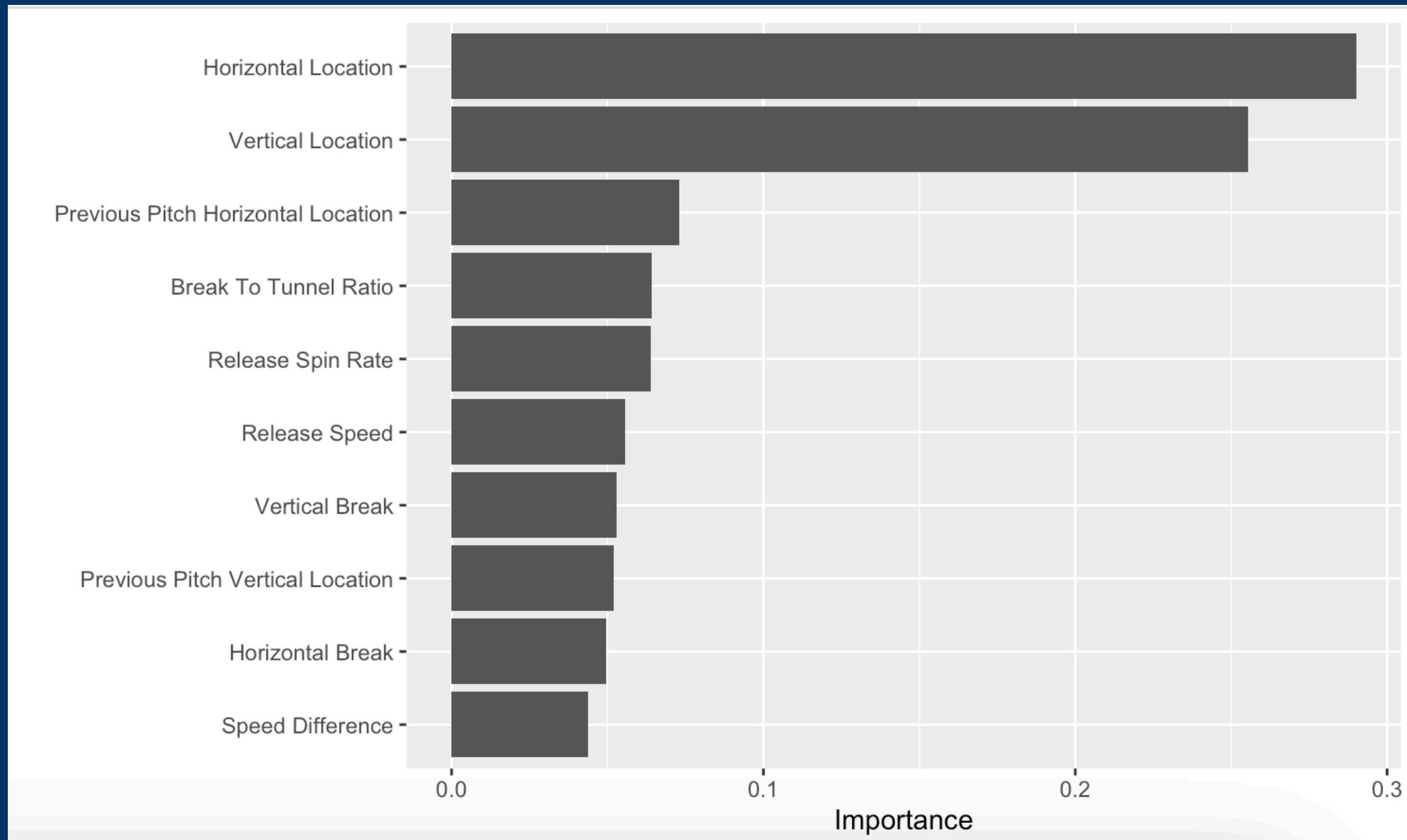


# Cutter -> Knuckle Curve | RHP -> RHH | Chase

**Training Sample: n = 998 pitches**

**Testing Sample: n = 430 pitches**

**Testing Accuracy: 70.47%**

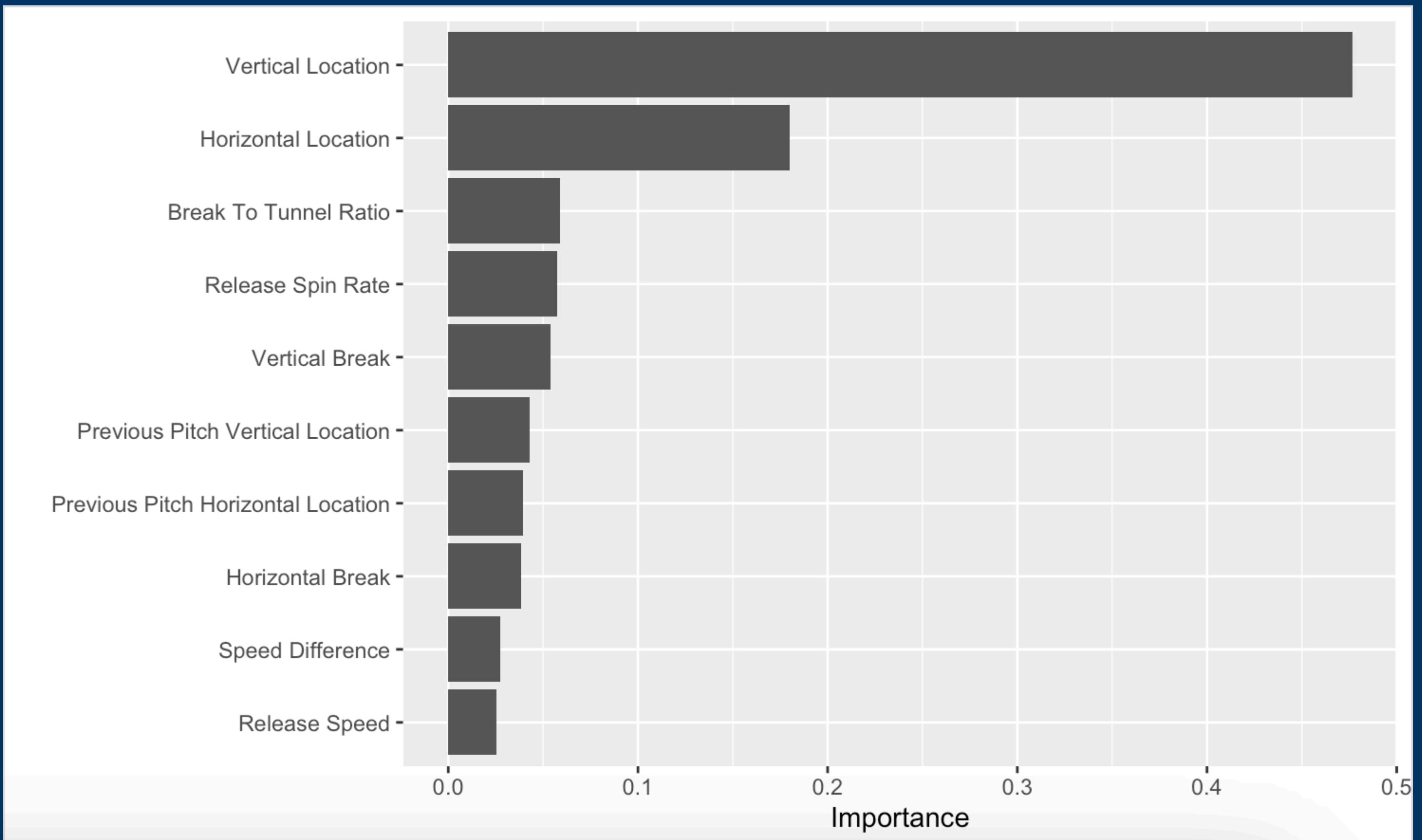


# Cutter -> Slider | RHP -> RHH | Whiff

**Training Sample: n = 1864 pitches**

**Testing Sample: n = 800 pitches**

**Testing Accuracy: 75.63%**

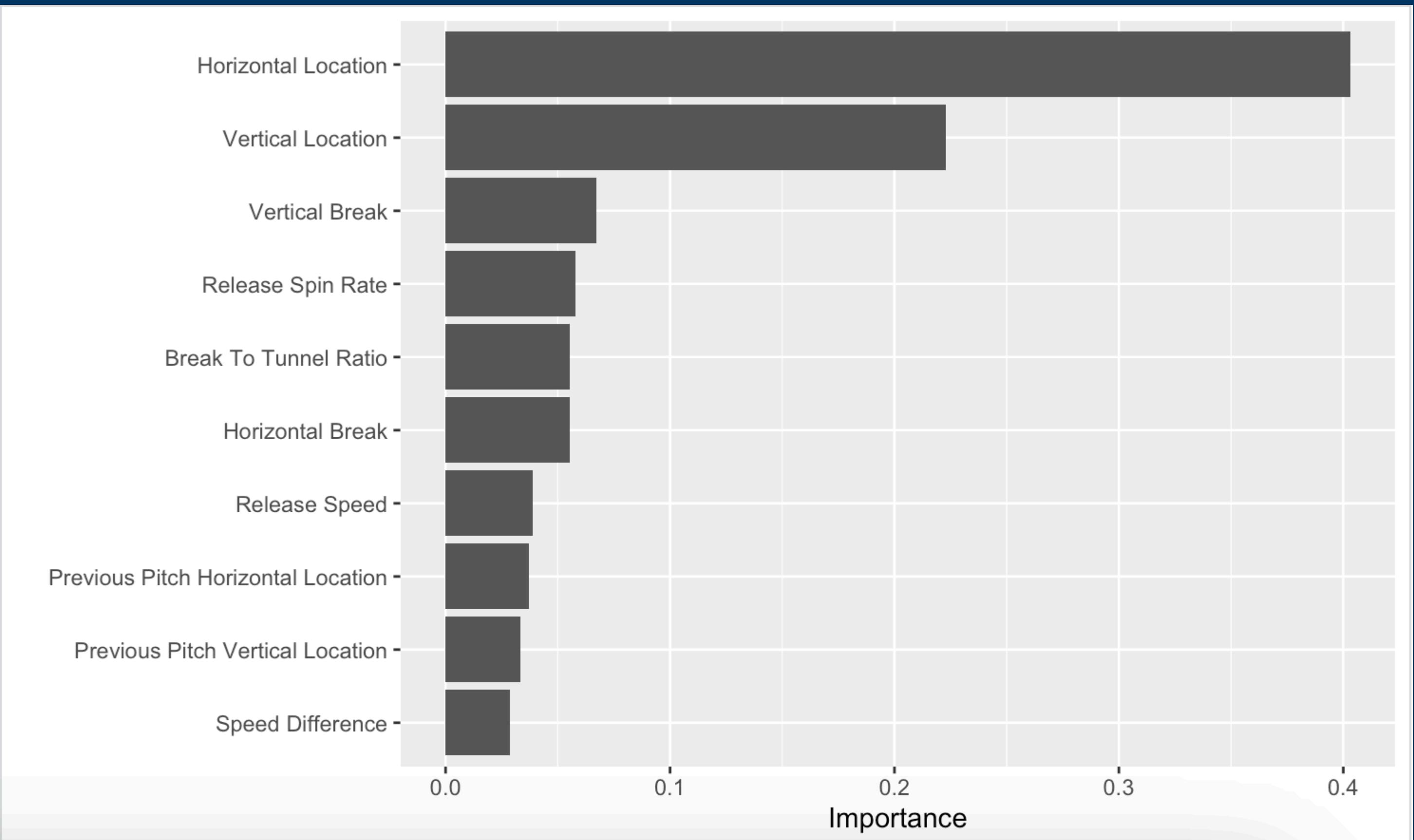


# Cutter -> Slider | RHP -> RHH | Chase

**Training Sample: n = 2458 pitches**

**Testing Sample: n = 1054 pitches**

**Testing Accuracy: 67.55%**

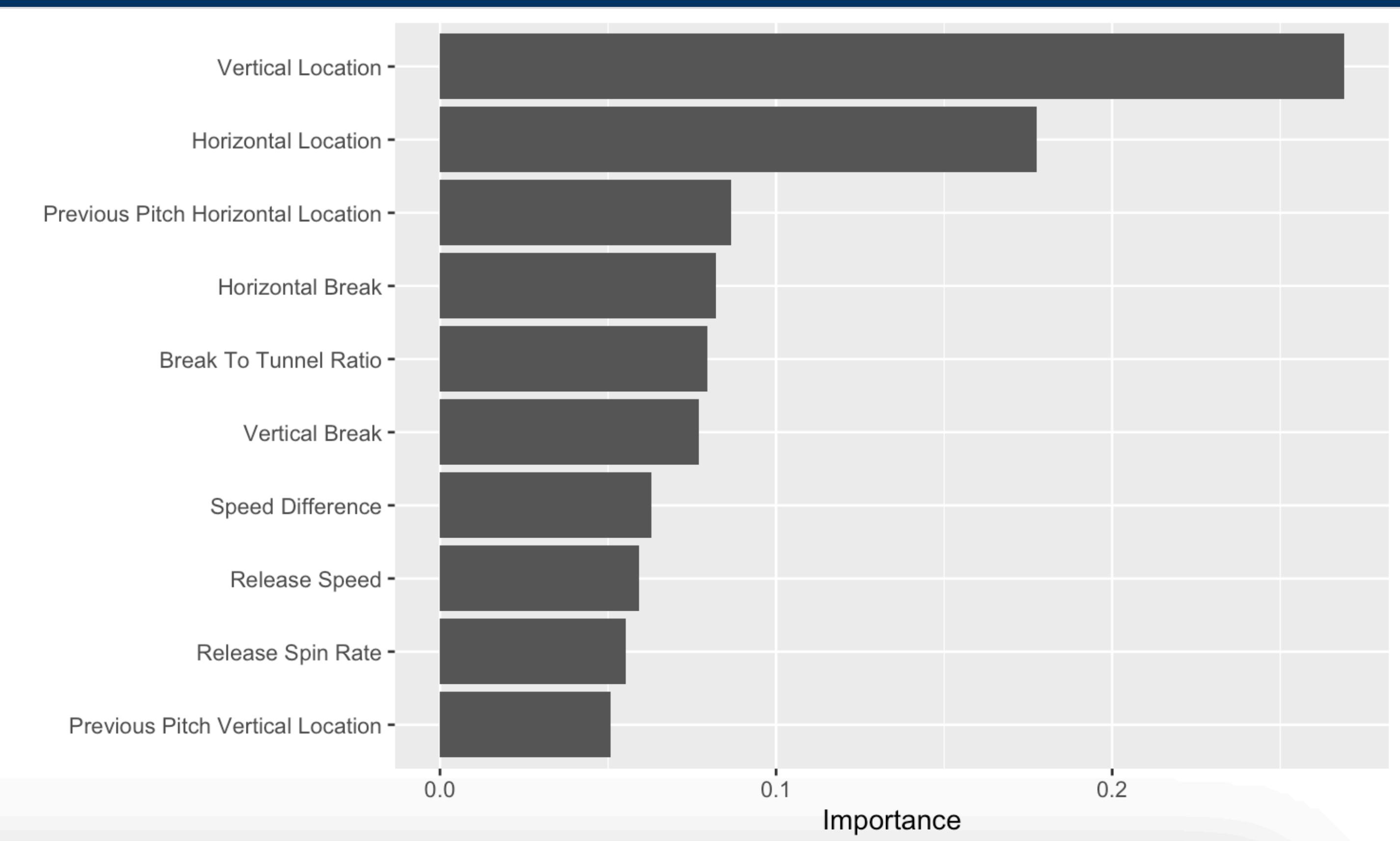


# Cutter -> Sweeper | RHP -> RHH | Whiff

**Training Sample: n = 548 pitches**

**Testing Sample: n = 236 pitches**

**Testing Accuracy: 69.07%**

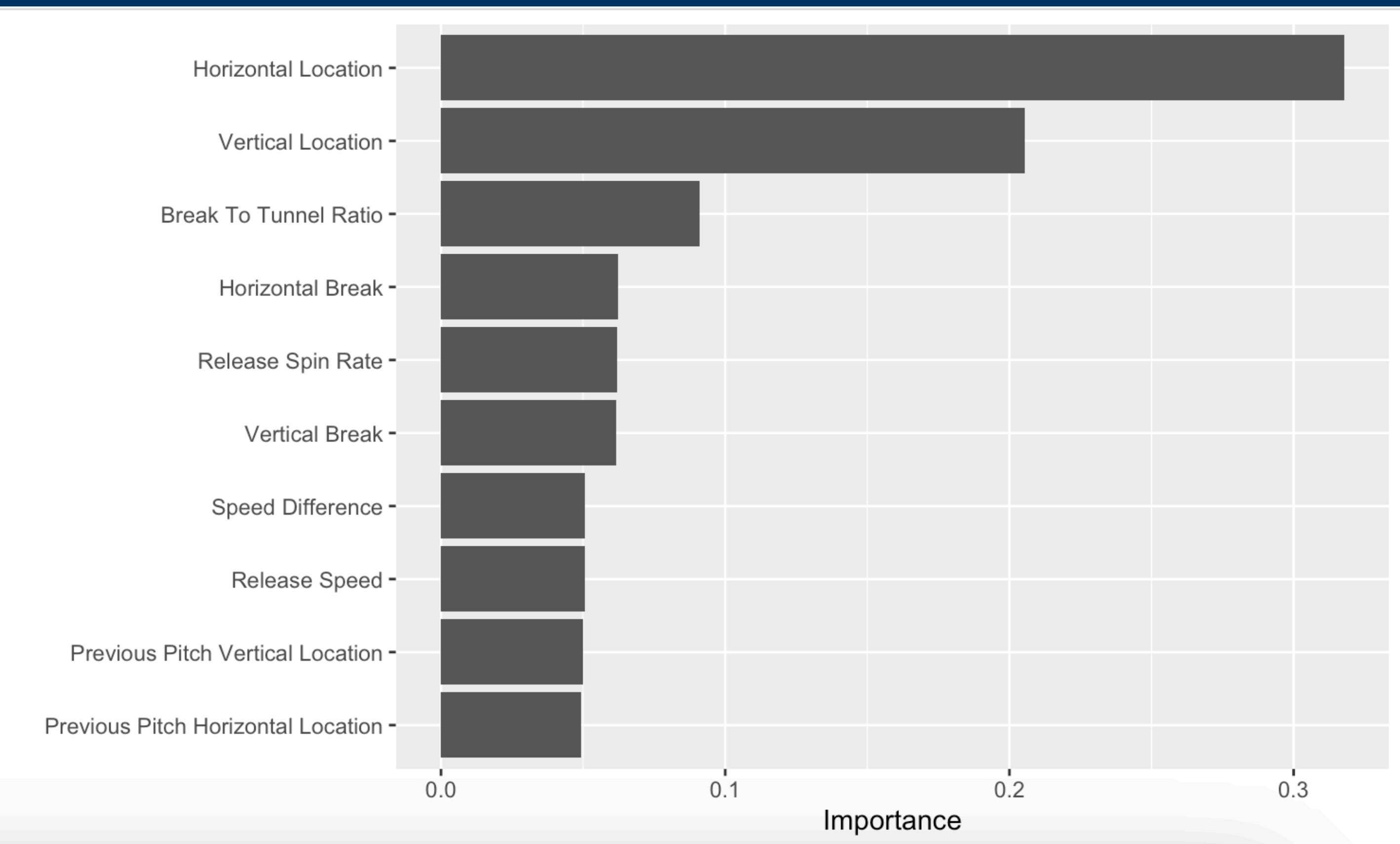


# Cutter -> Sweeper | RHP -> RHH | Chase

**Training Sample: n = 652 pitches**

**Testing Sample: n = 282 pitches**

**Testing Accuracy: 71.99%**

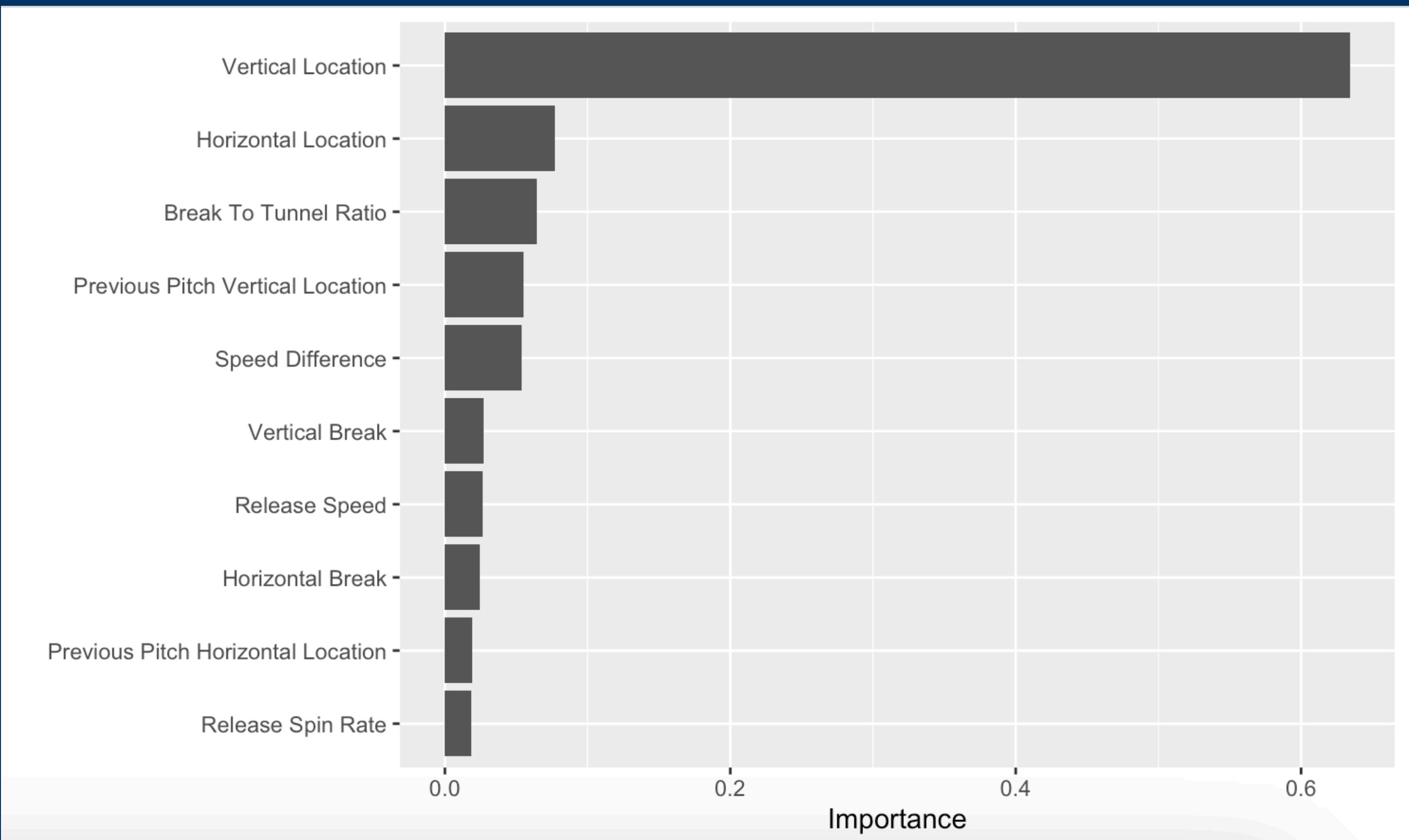


# Four-Seam -> Changeup | RHP -> RHH | Whiff

**Training Sample: n = 8242 pitches**

**Testing Sample: n = 3534 pitches**

**Testing Accuracy: 67.35%**

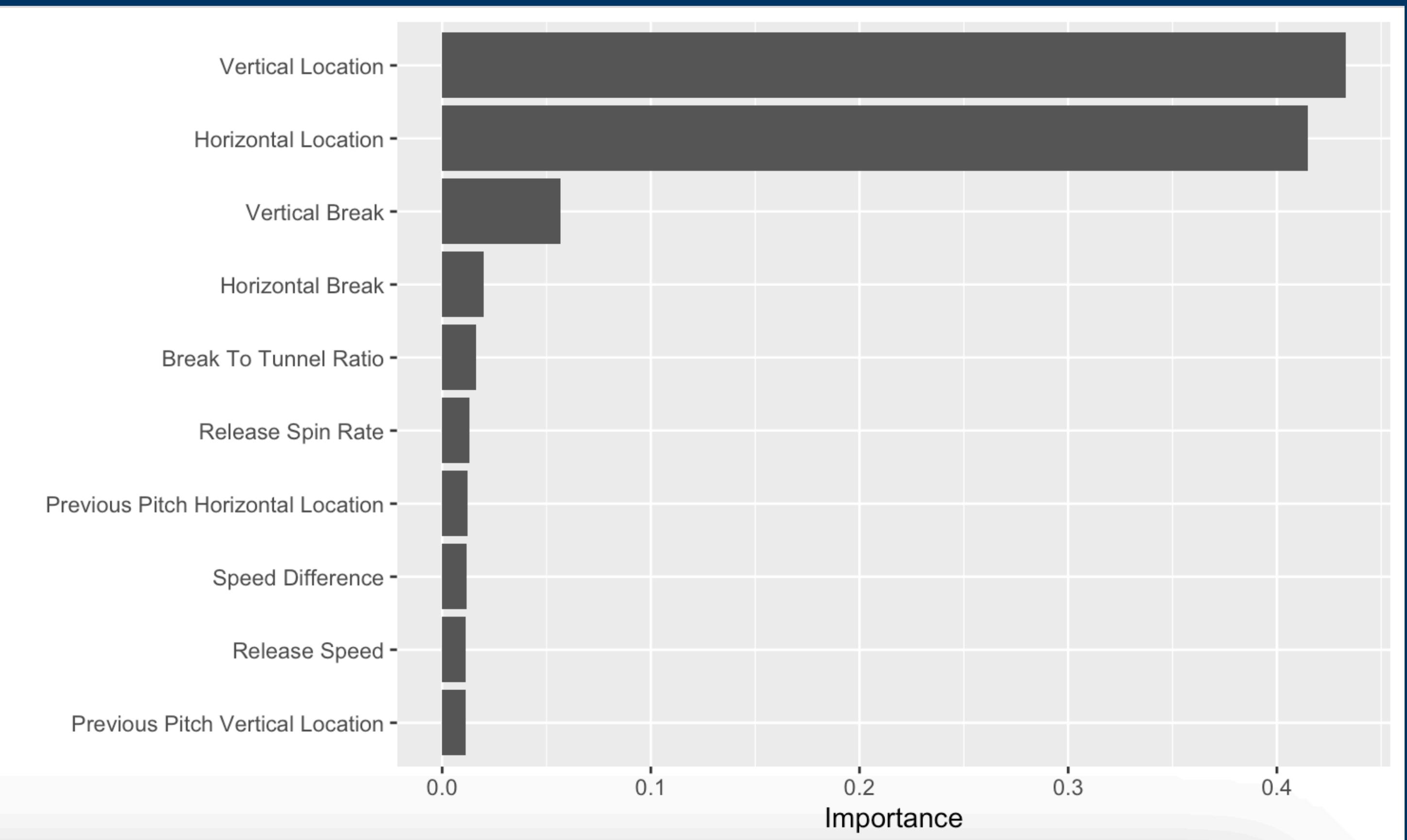


# Four-Seam -> Changeup | RHP -> RHH | Chase

**Training Sample: n = 11422 pitches**

**Testing Sample: n = 4896 pitches**

**Testing Accuracy: 72.37%**

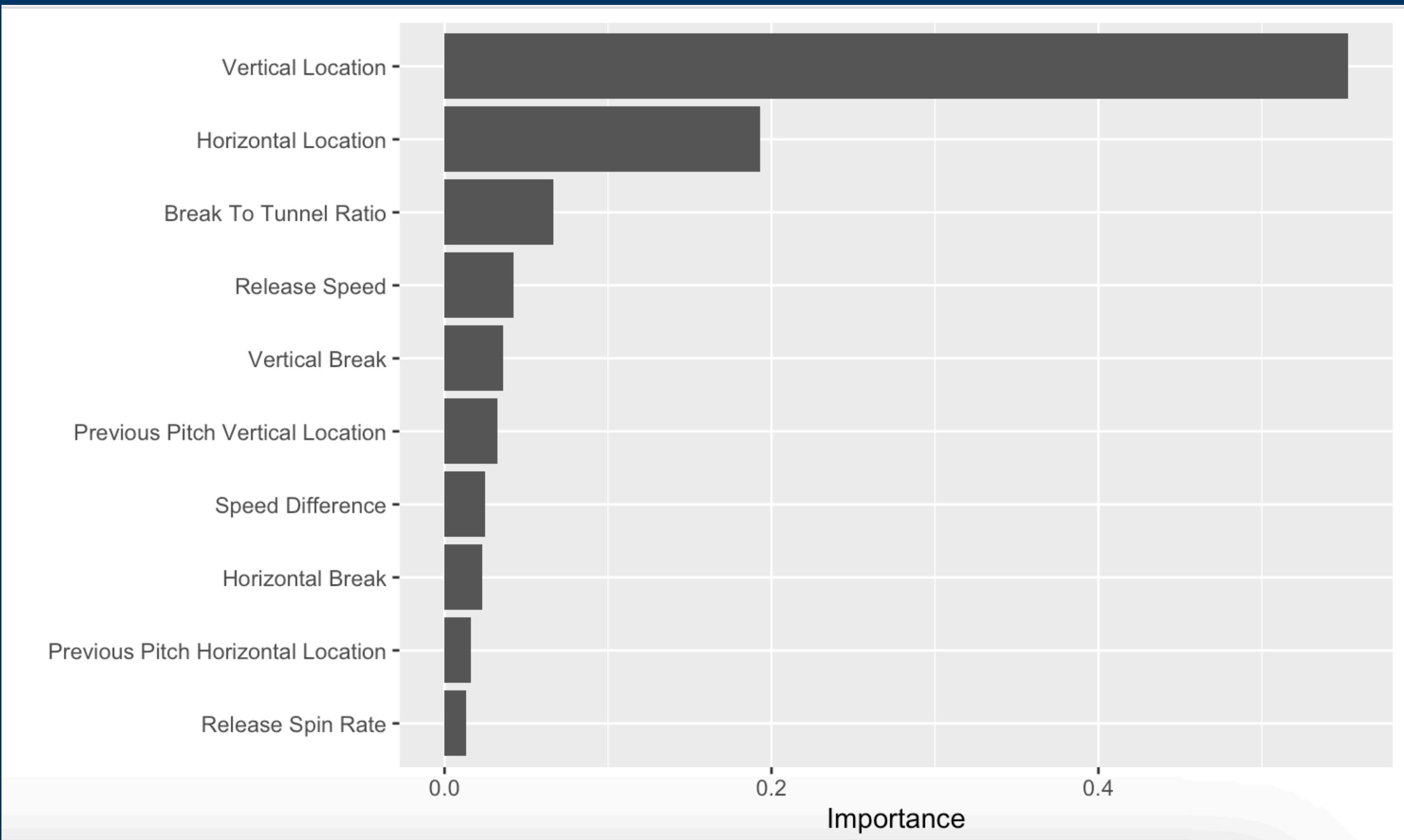


# Four-Seam -> Curveball | RHP -> RHH | Whiff

**Training Sample: n = 7318 pitches**

**Testing Sample: n = 3138 pitches**

**Testing Accuracy: 71.99%**

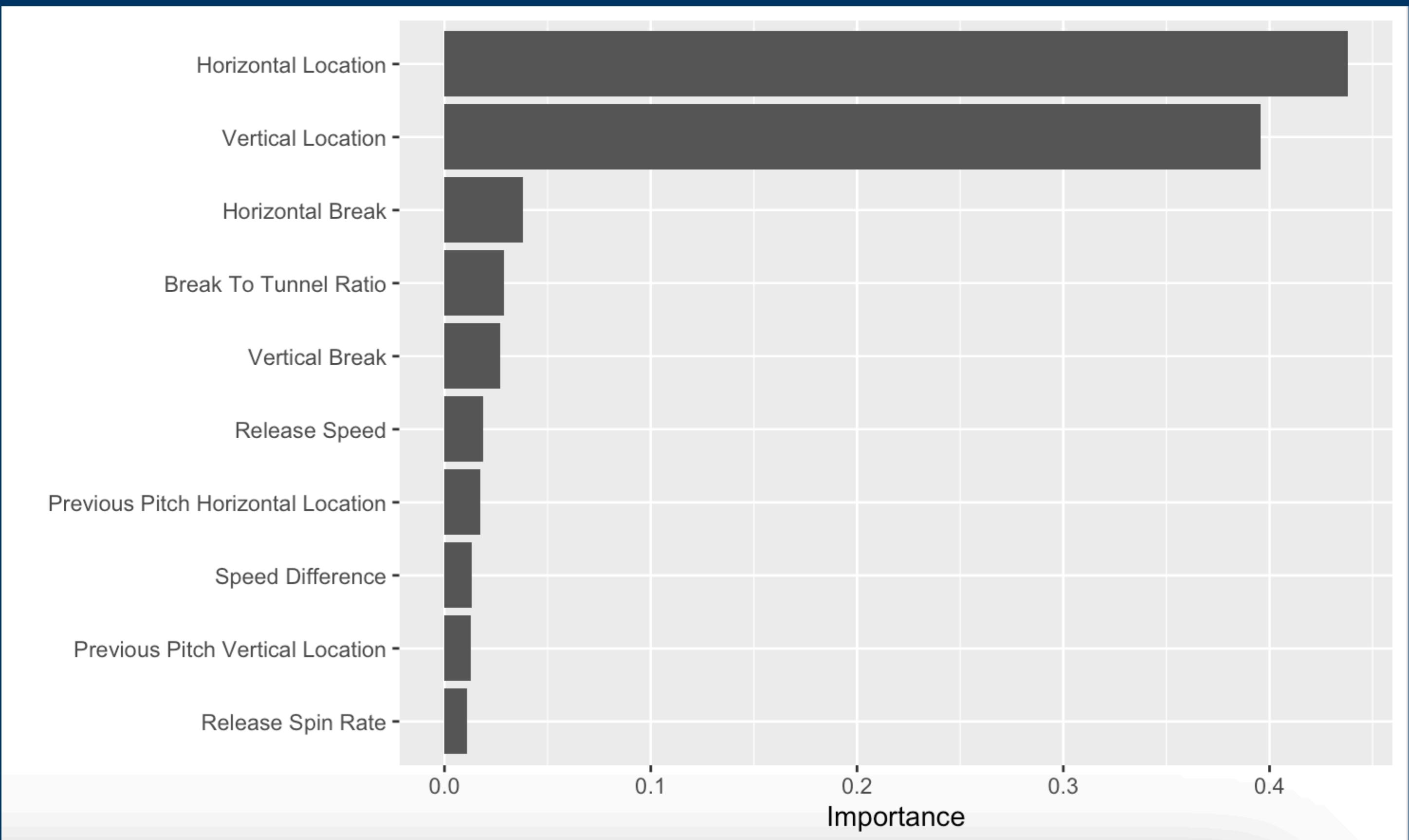


# Four-Seam -> Curveball | RHP -> RHH | Chase

**Training Sample: n = 10884 pitches**

**Testing Sample: n = 4666 pitches**

**Testing Accuracy: 70.83%**

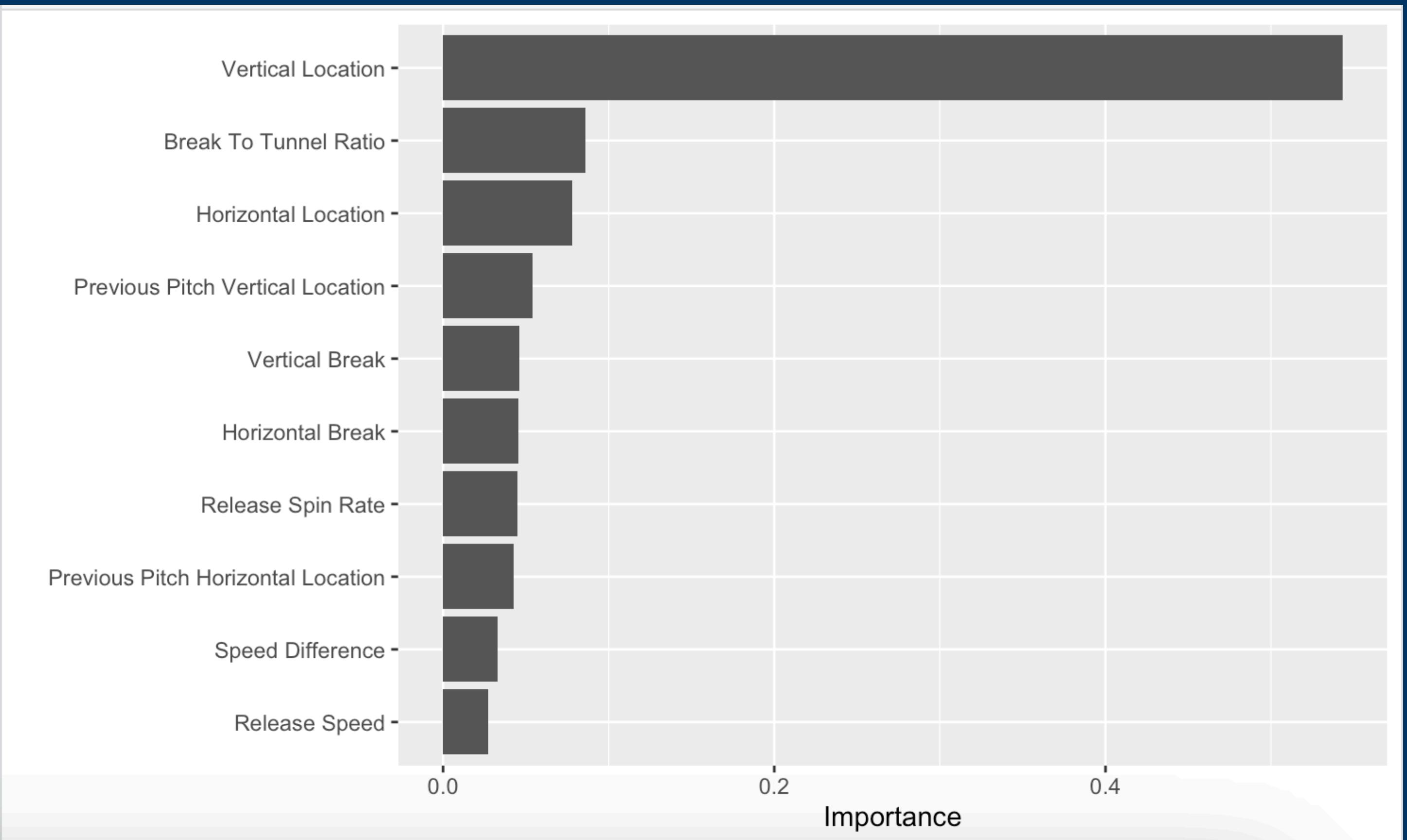


# Four-Seam -> Splitter | RHP -> RHH | Whiff

**Training Sample: n = 2702 pitches**

**Testing Sample: n = 1160 pitches**

**Testing Accuracy: 67.16%**

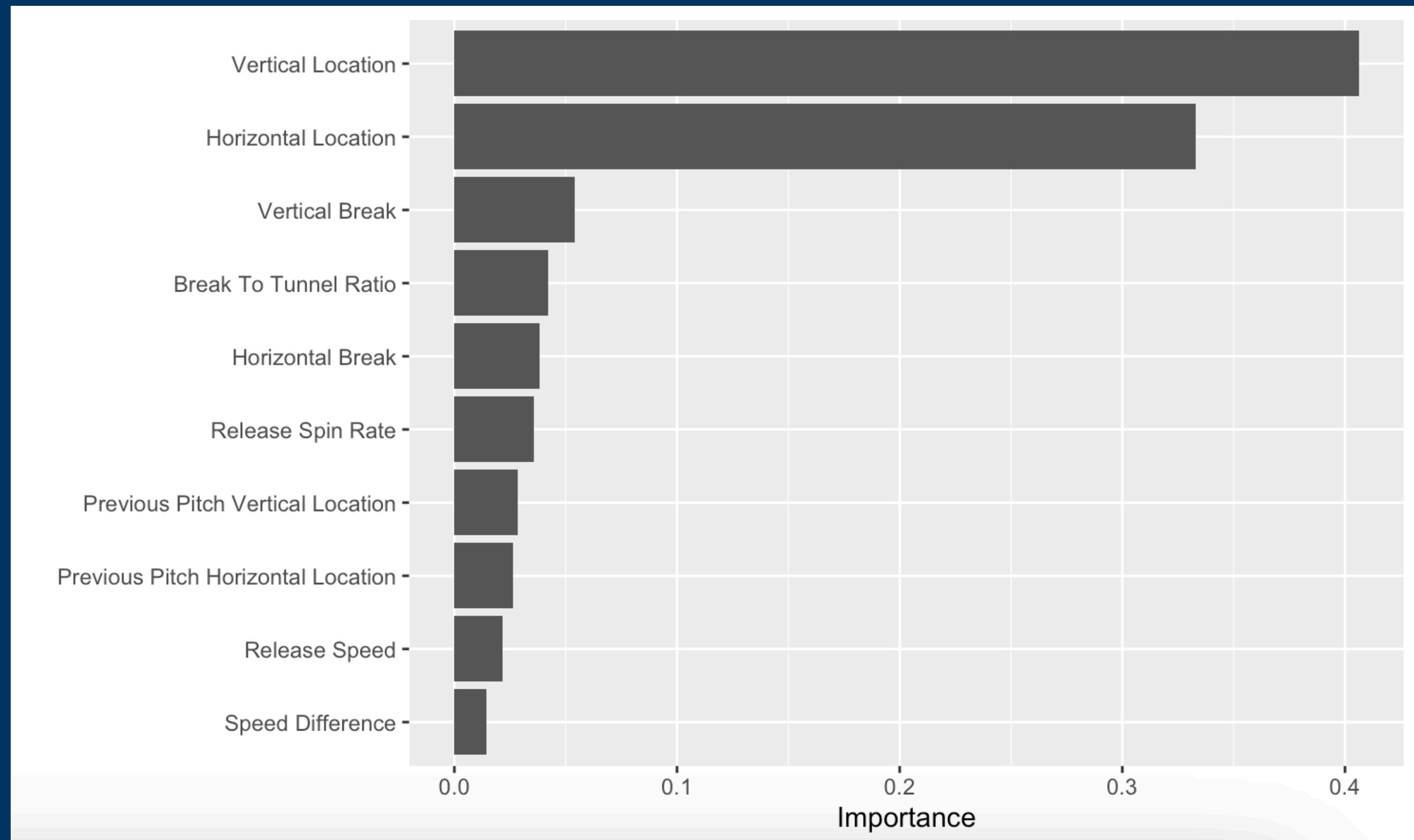


# Four-Seam -> Splitter | RHP -> RHH | Chase

**Training Sample: n = 3722 pitches**

**Testing Sample: n = 1598 pitches**

**Testing Accuracy: 73.09%**

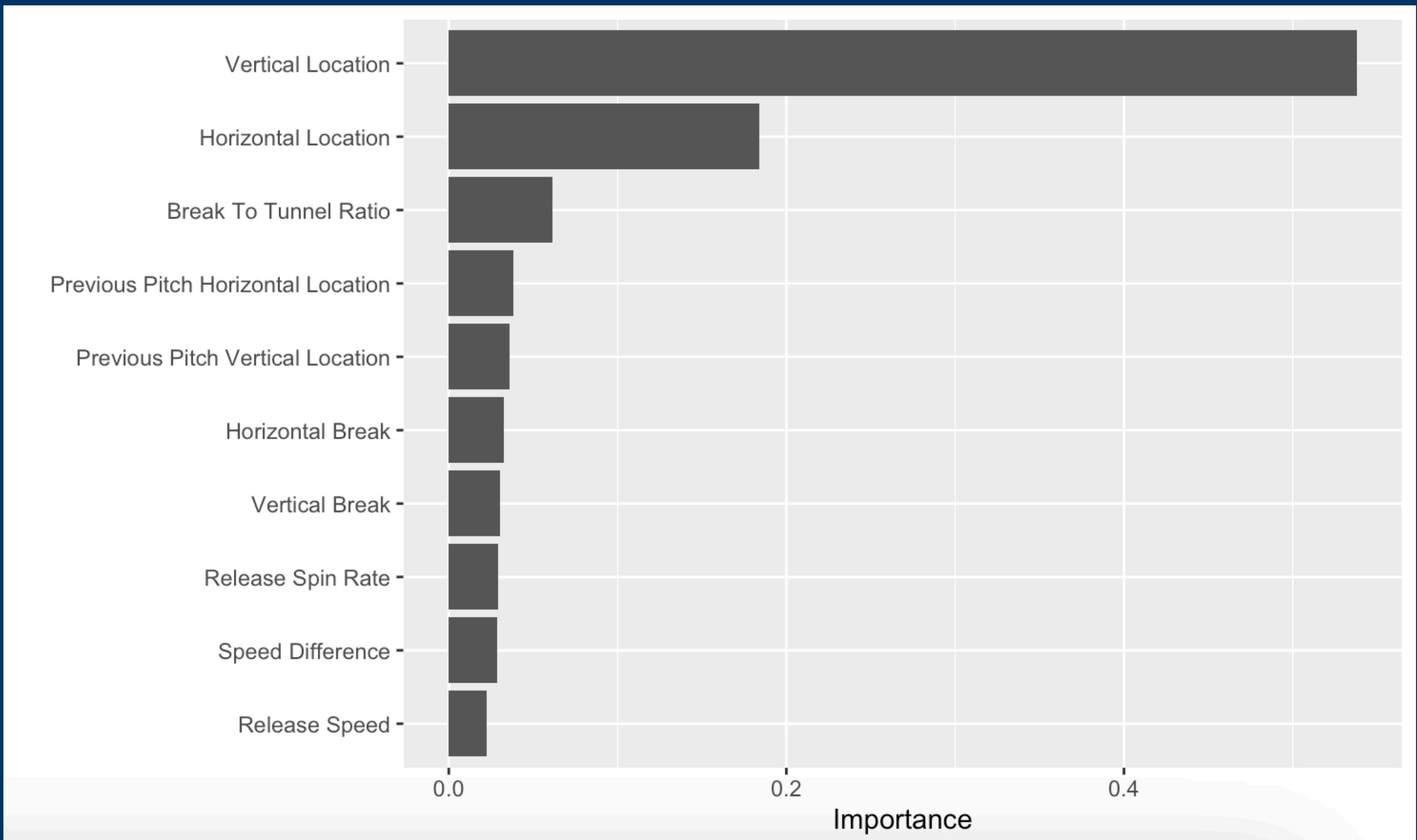


# Four-Seam -> Knuckle Curve | RHP -> RHH | Whiff

**Training Sample: n = 2898 pitches**

**Testing Sample: n = 1244 pitches**

**Testing Accuracy: 76.37%**

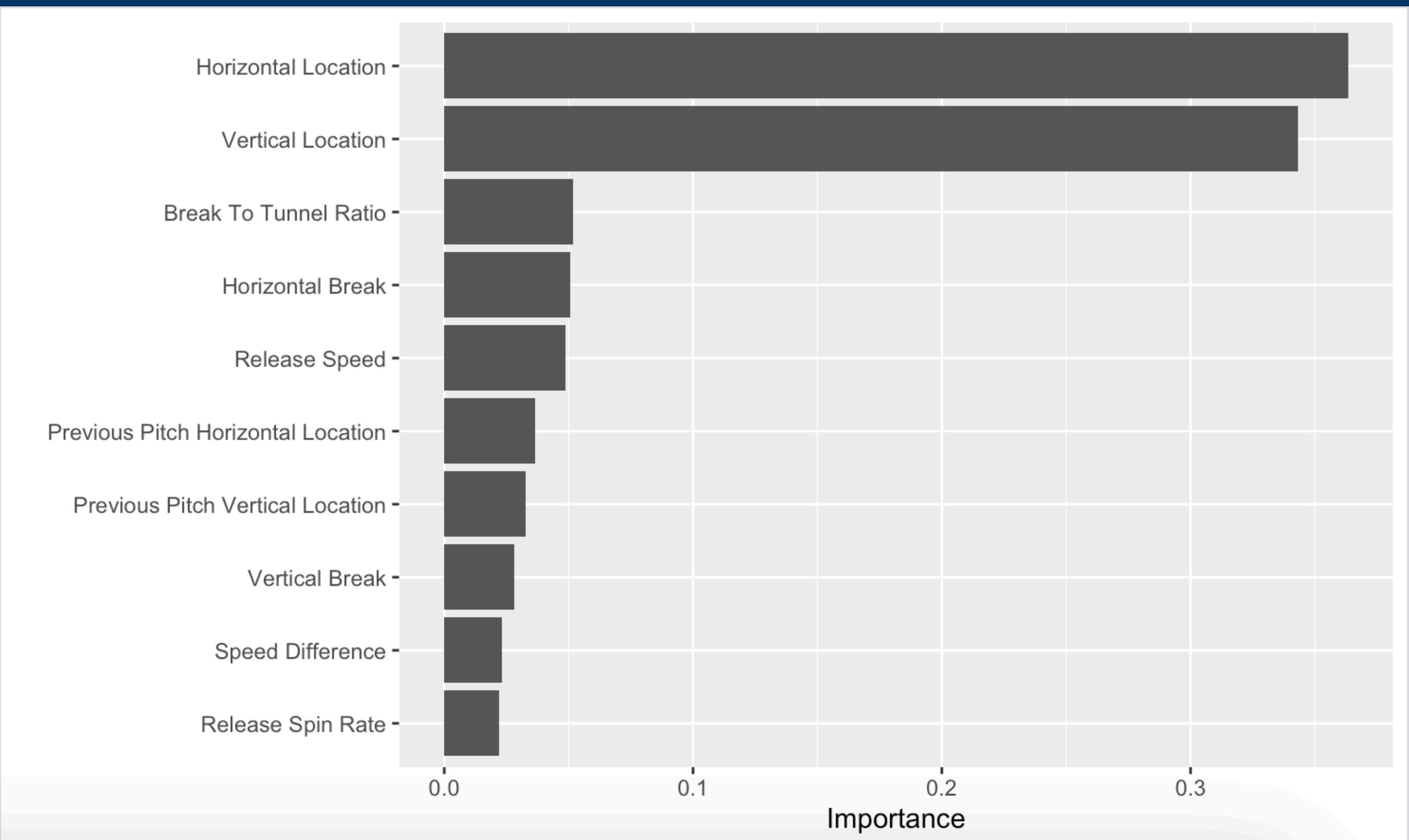


# Four-Seam -> Knuckle Curve | RHP -> RHH | Chase

**Training Sample: n = 4086 pitches**

**Testing Sample: n = 1754 pitches**

**Testing Accuracy: 69.44%**

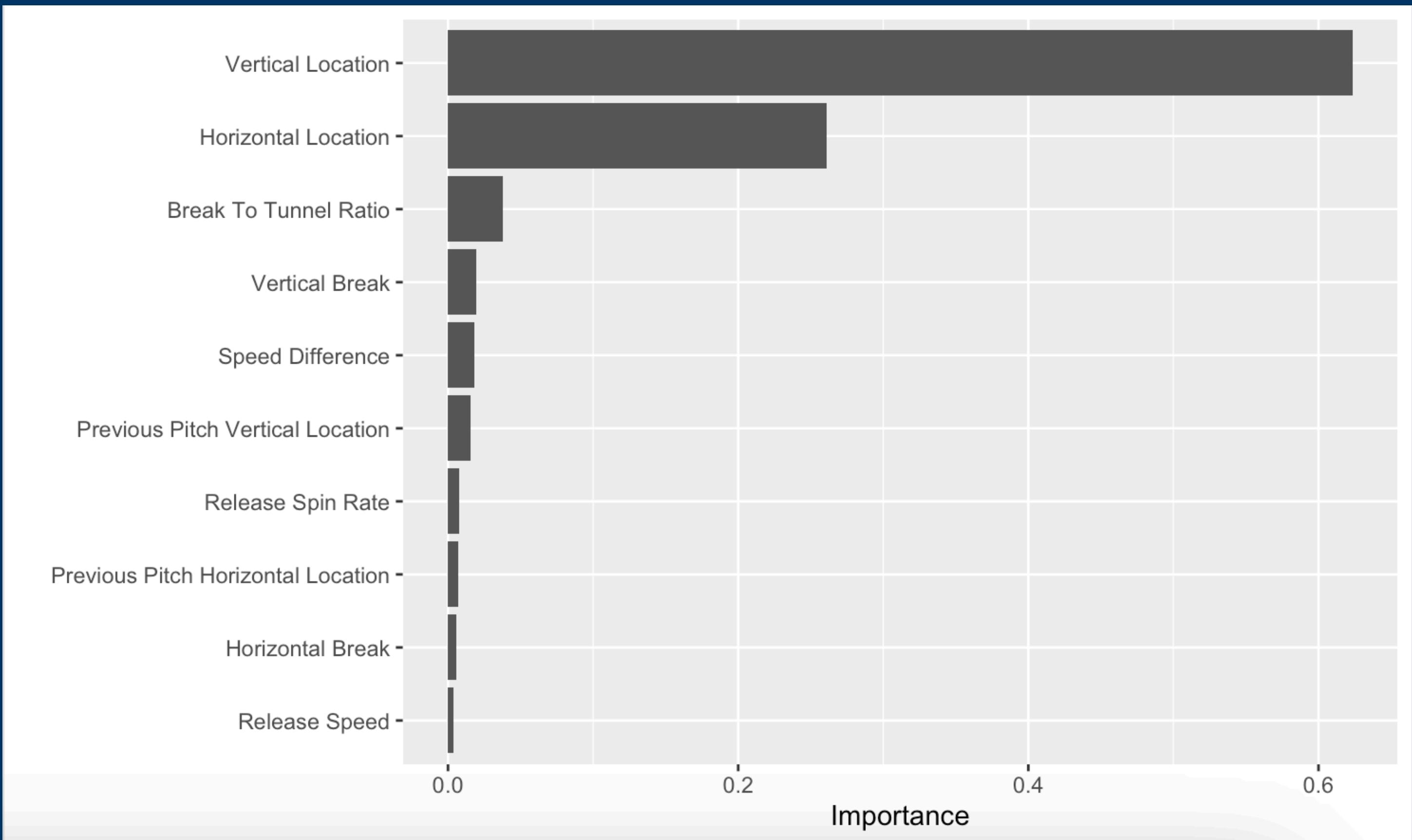


# Four-Seam -> Slider | RHP -> RHH | Whiff

**Training Sample: n = 27356 pitches**

**Testing Sample: n = 11726 pitches**

**Testing Accuracy: 71.87%**

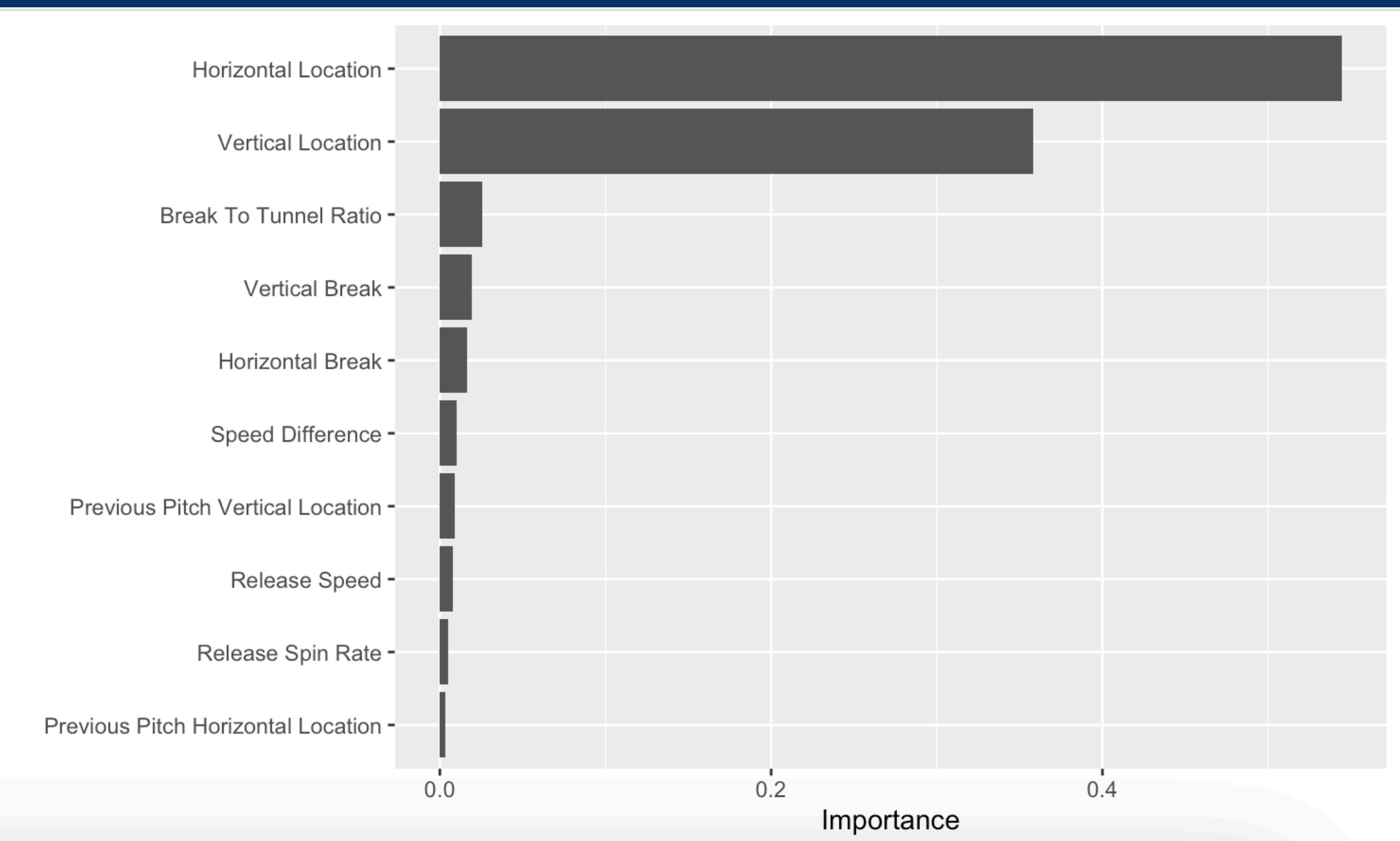


# Four-Seam -> Slider | RHP -> RHH | Chase

**Training Sample: n = 34760 pitches**

**Testing Sample: n = 14898 pitches**

**Testing Accuracy: 67.99%**

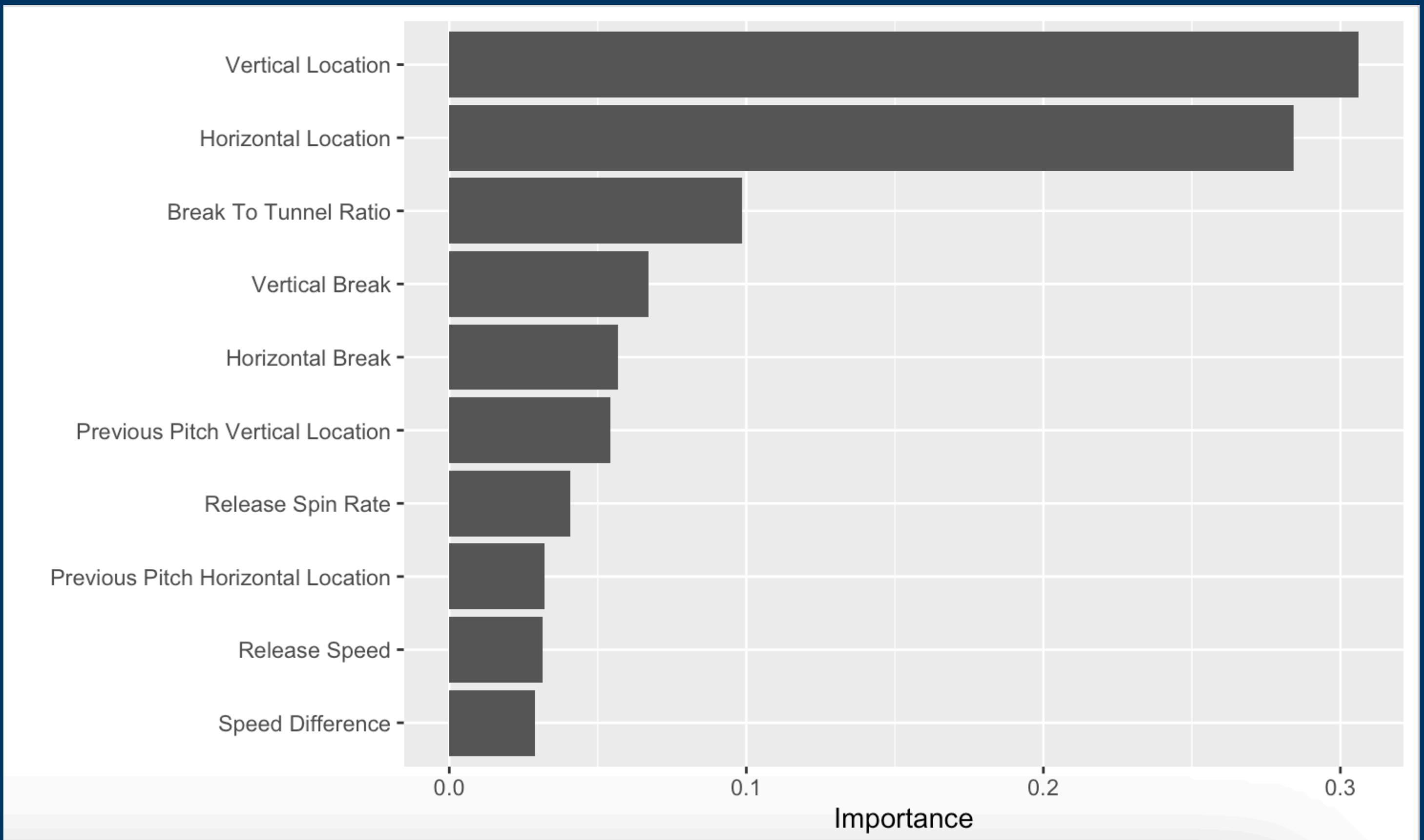


# Four-Seam -> Sweeper | RHP -> RHH | Whiff

**Training Sample: n = 1938 pitches**

**Testing Sample: n = 832 pitches**

**Testing Accuracy: 70.07%**

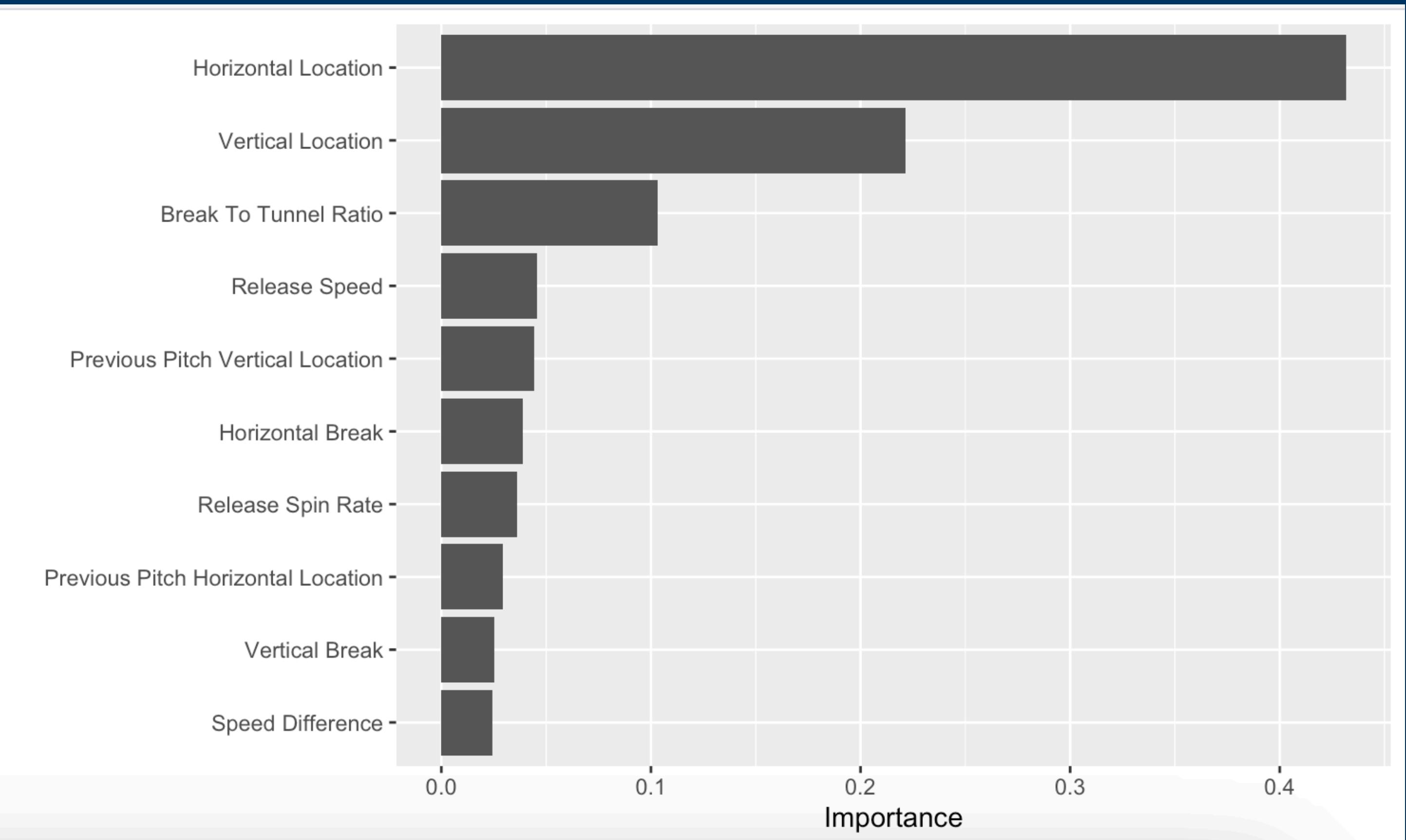


# Four-Seam -> Sweeper | RHP -> RHH | Chase

**Training Sample: n = 2696 pitches**

**Testing Sample: n = 1158 pitches**

**Testing Accuracy: 67.53%**

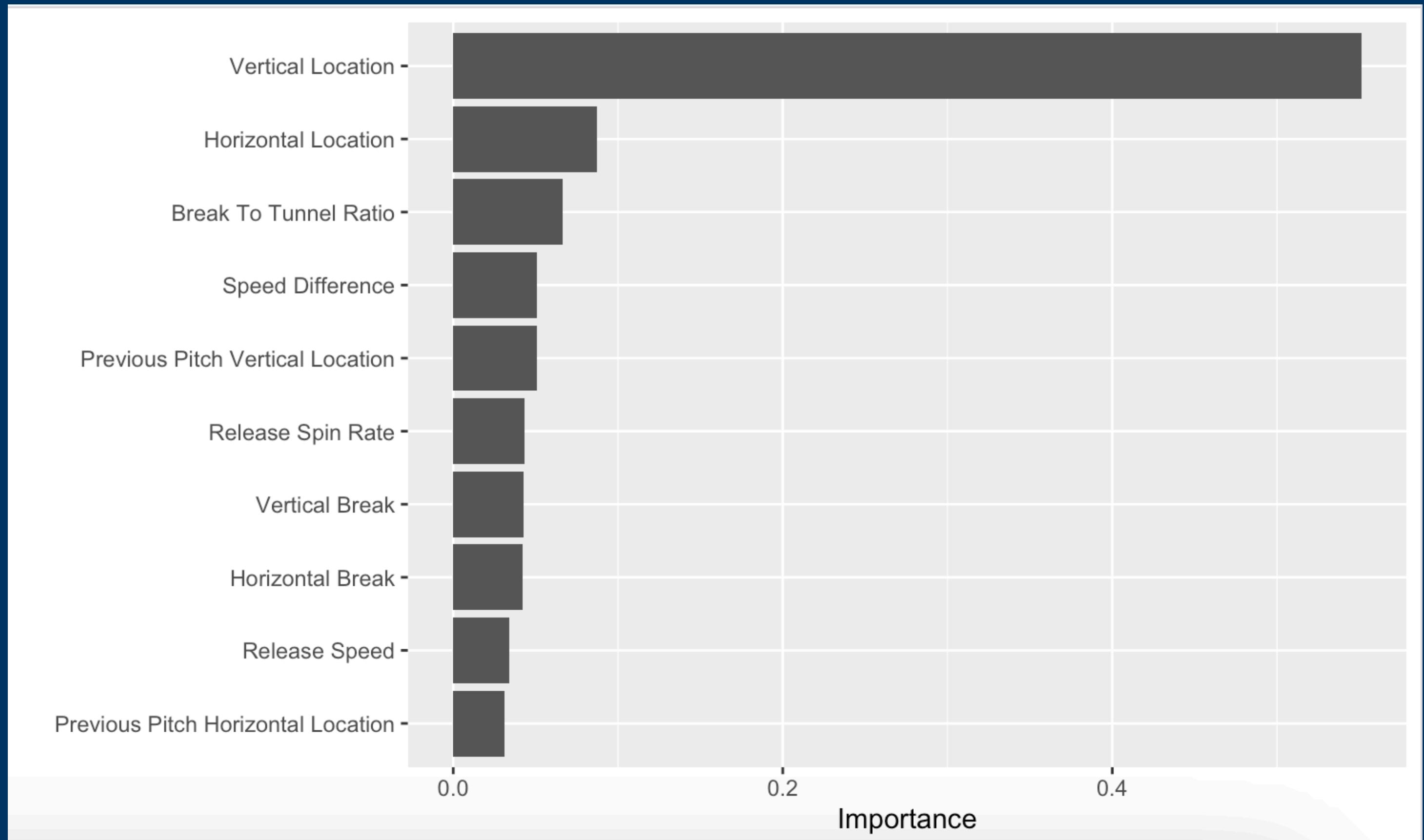


# Sinker -> Changeup | RHP -> RHH | Whiff

**Training Sample: n = 5142 pitches**

**Testing Sample: n = 2206 pitches**

**Testing Accuracy: 67.36%**

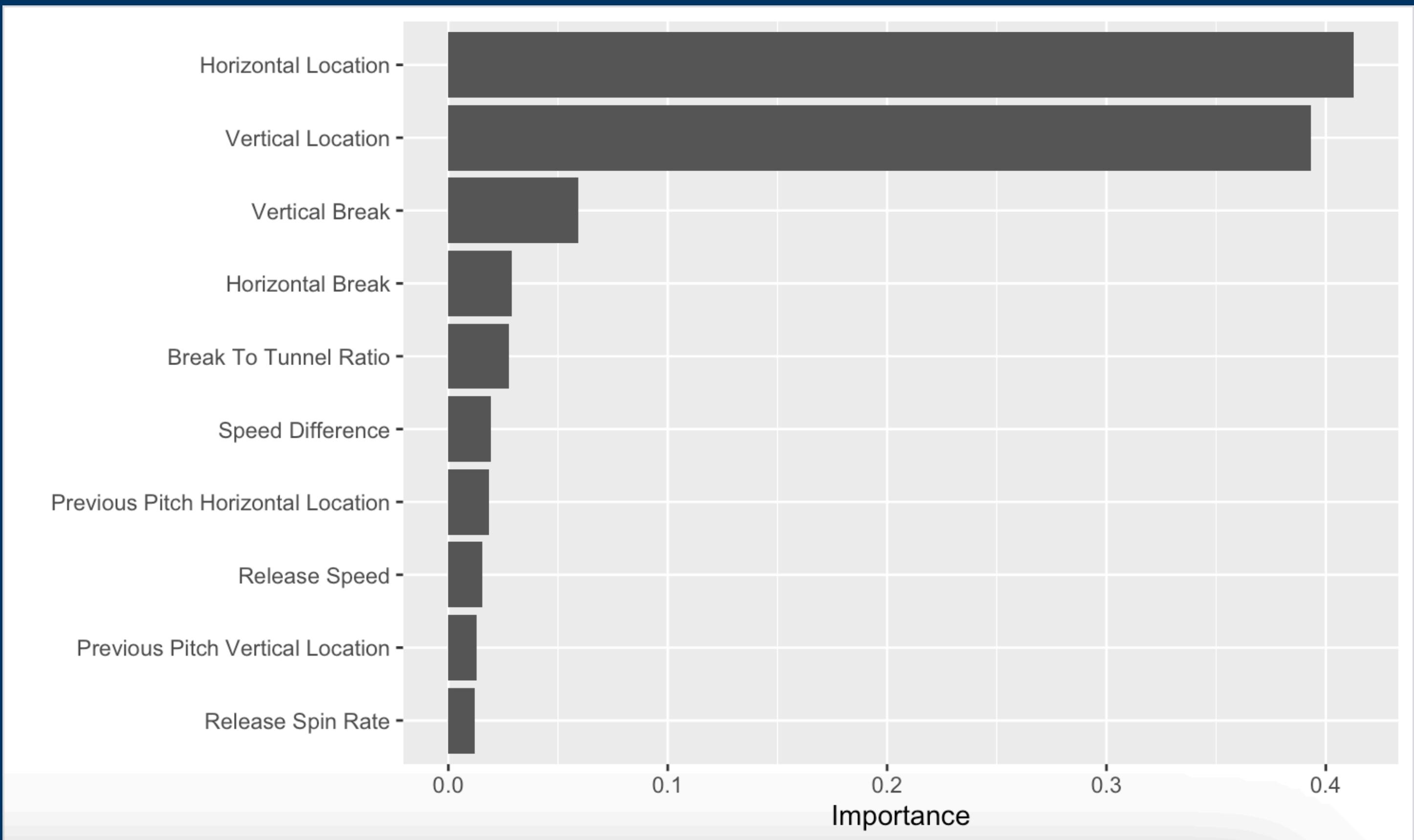


# Sinker -> Changeup | RHP -> RHH | Chase

**Training Sample: n = 7158 pitches**

**Testing Sample: n = 3068 pitches**

**Testing Accuracy: 72.07%**

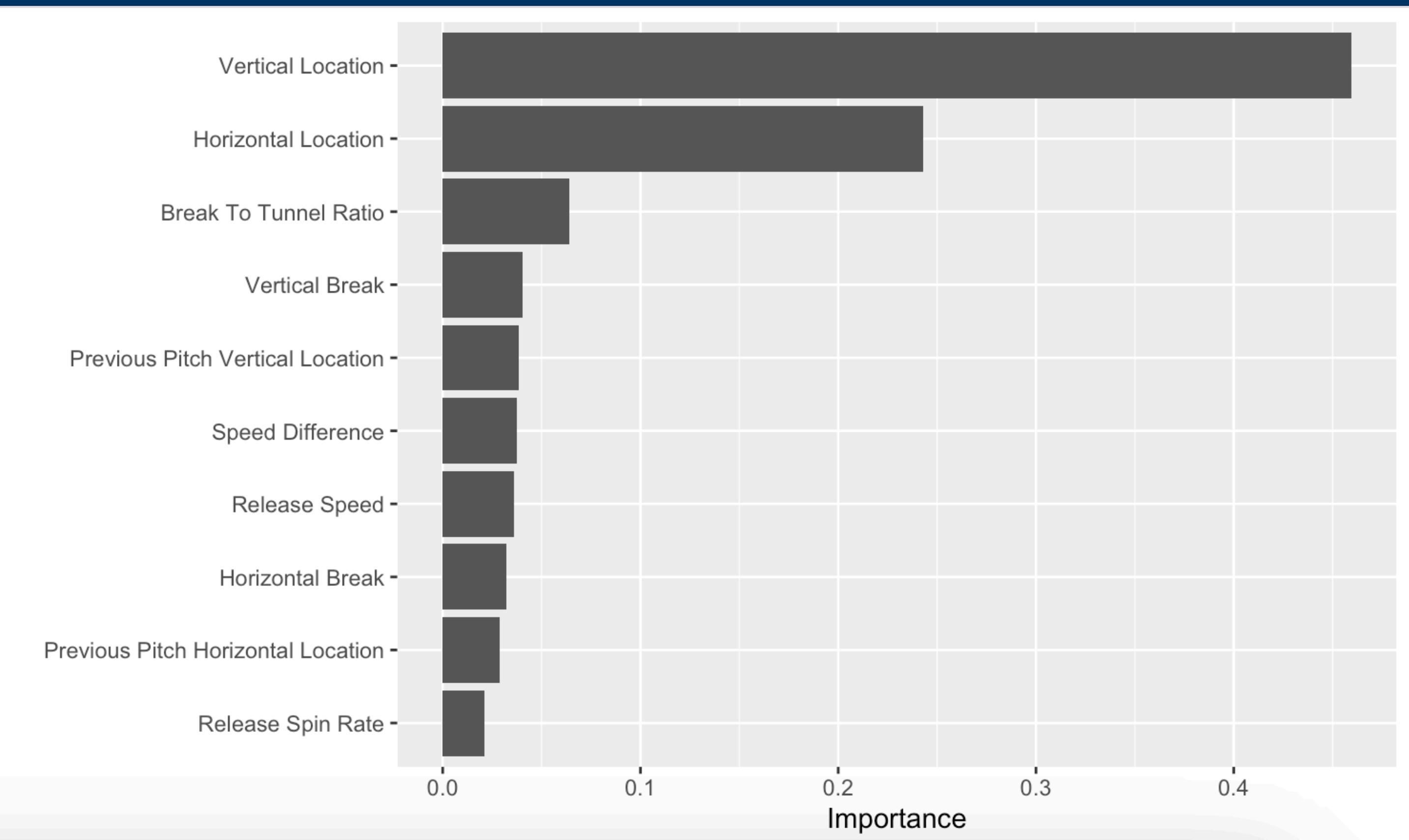


# Sinker -> Curveball | RHP -> RHH | Whiff

**Training Sample: n = 4284 pitches**

**Testing Sample: n = 1836 pitches**

**Testing Accuracy: 72.66%**

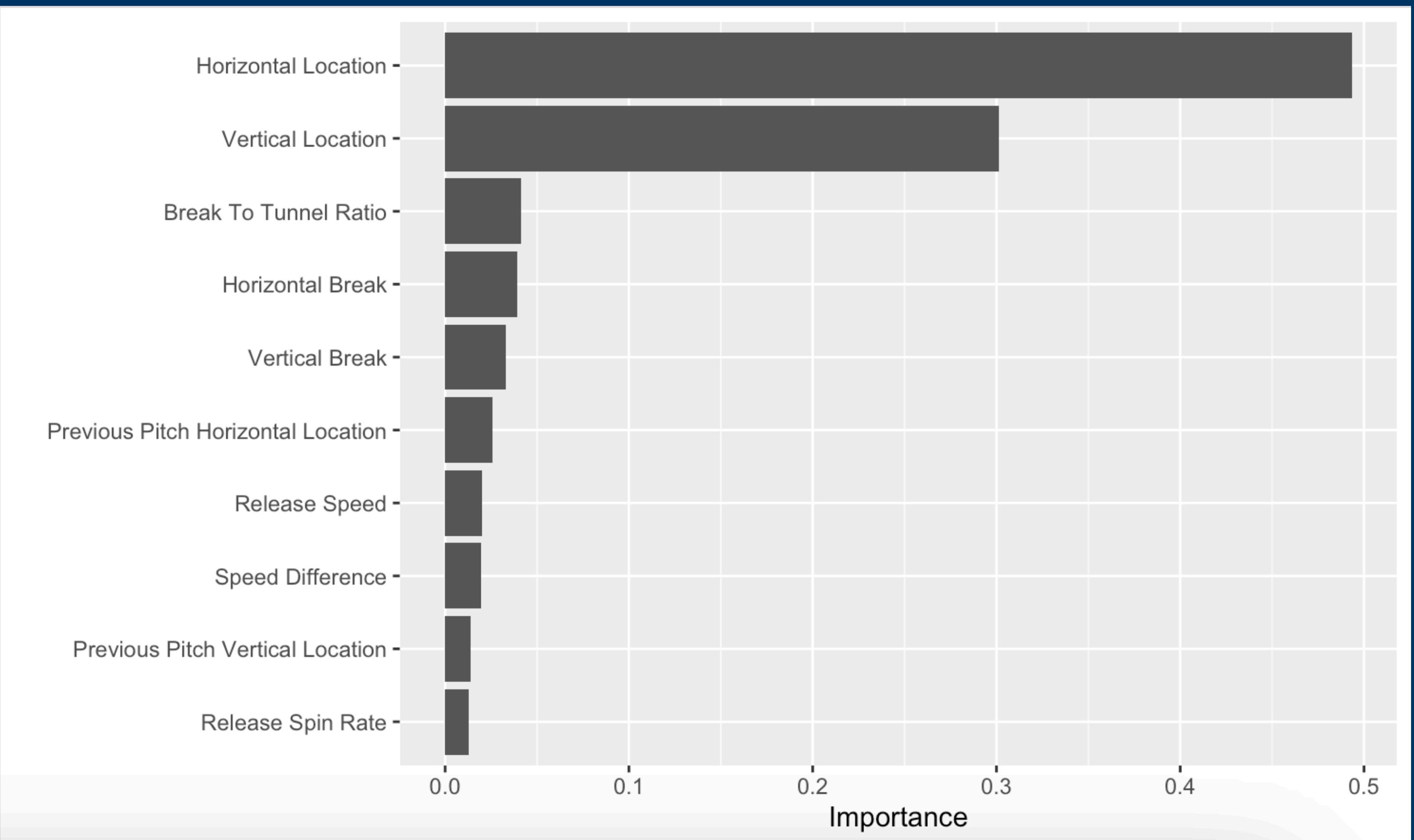


# Sinker -> Curveball | RHP -> RHH | Chase

**Training Sample: n = 5876 pitches**

**Testing Sample: n = 2520 pitches**

**Testing Accuracy: 71.35%**

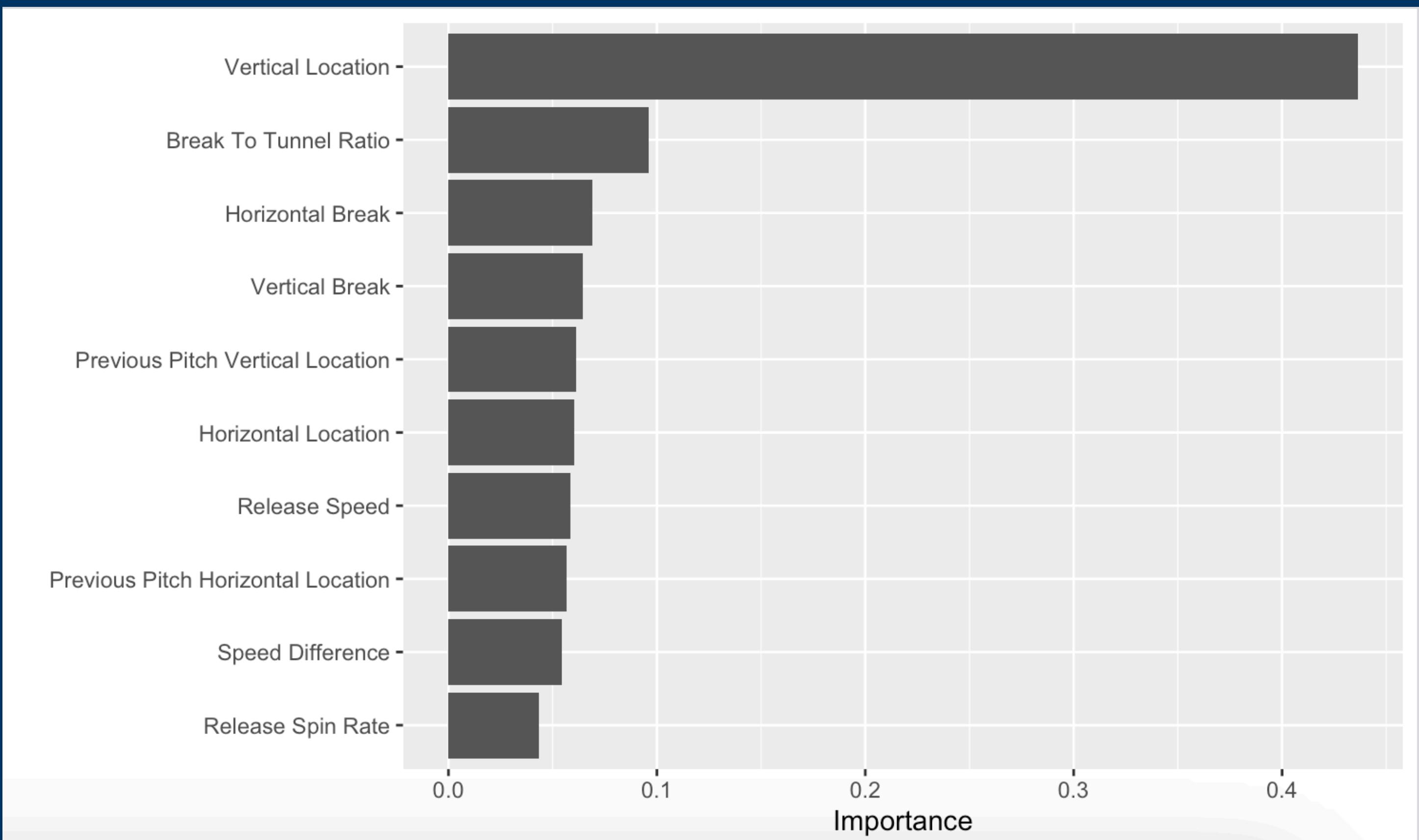


# Sinker -> Splitter | RHP -> RHH | Whiff

**Training Sample: n = 978 pitches**

**Testing Sample: n = 420 pitches**

**Testing Accuracy: 71.19%**

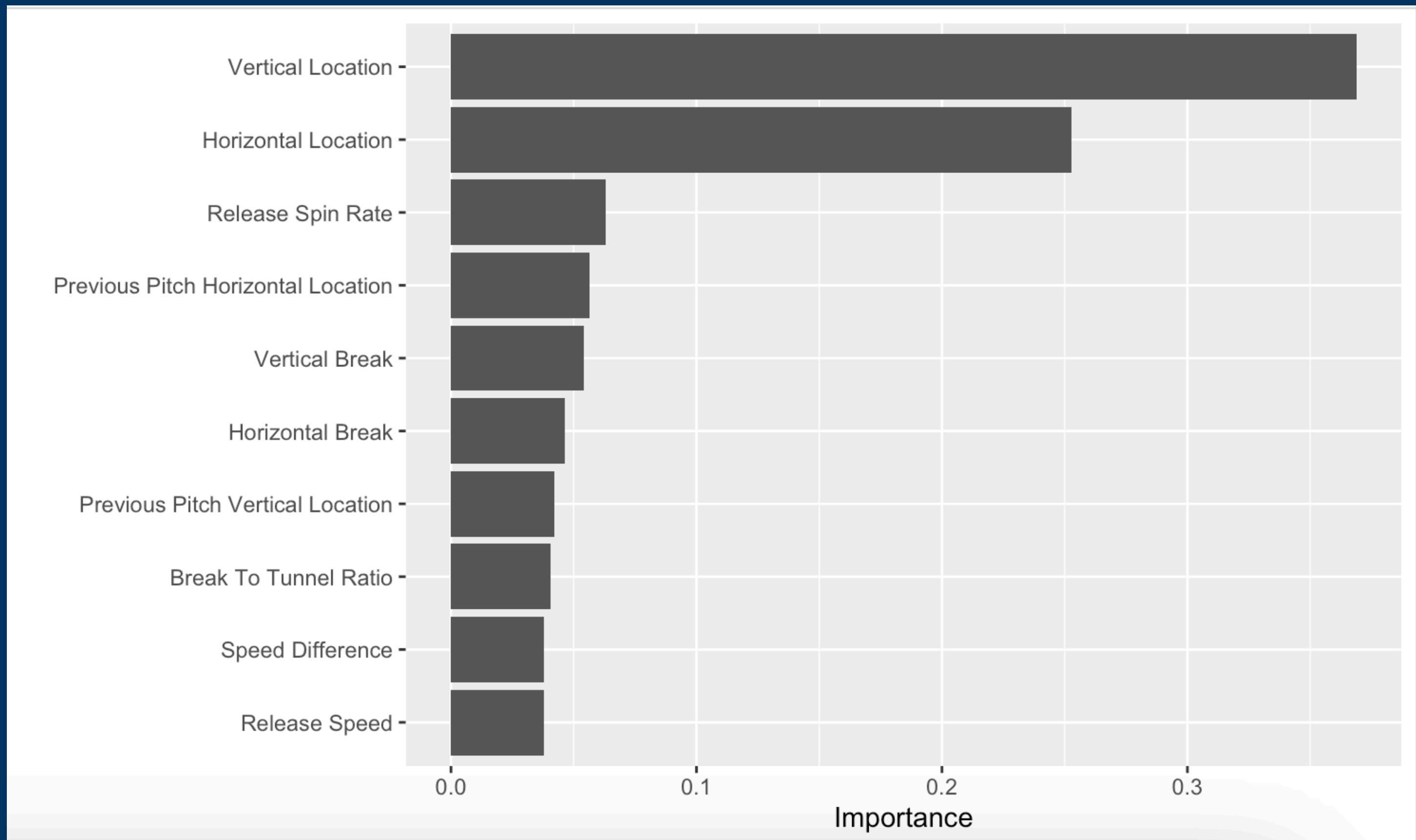


# Sinker -> Splitter | RHP -> RHH | Chase

**Training Sample: n = 1498 pitches**

**Testing Sample: n = 644 pitches**

**Testing Accuracy: 70.81%**

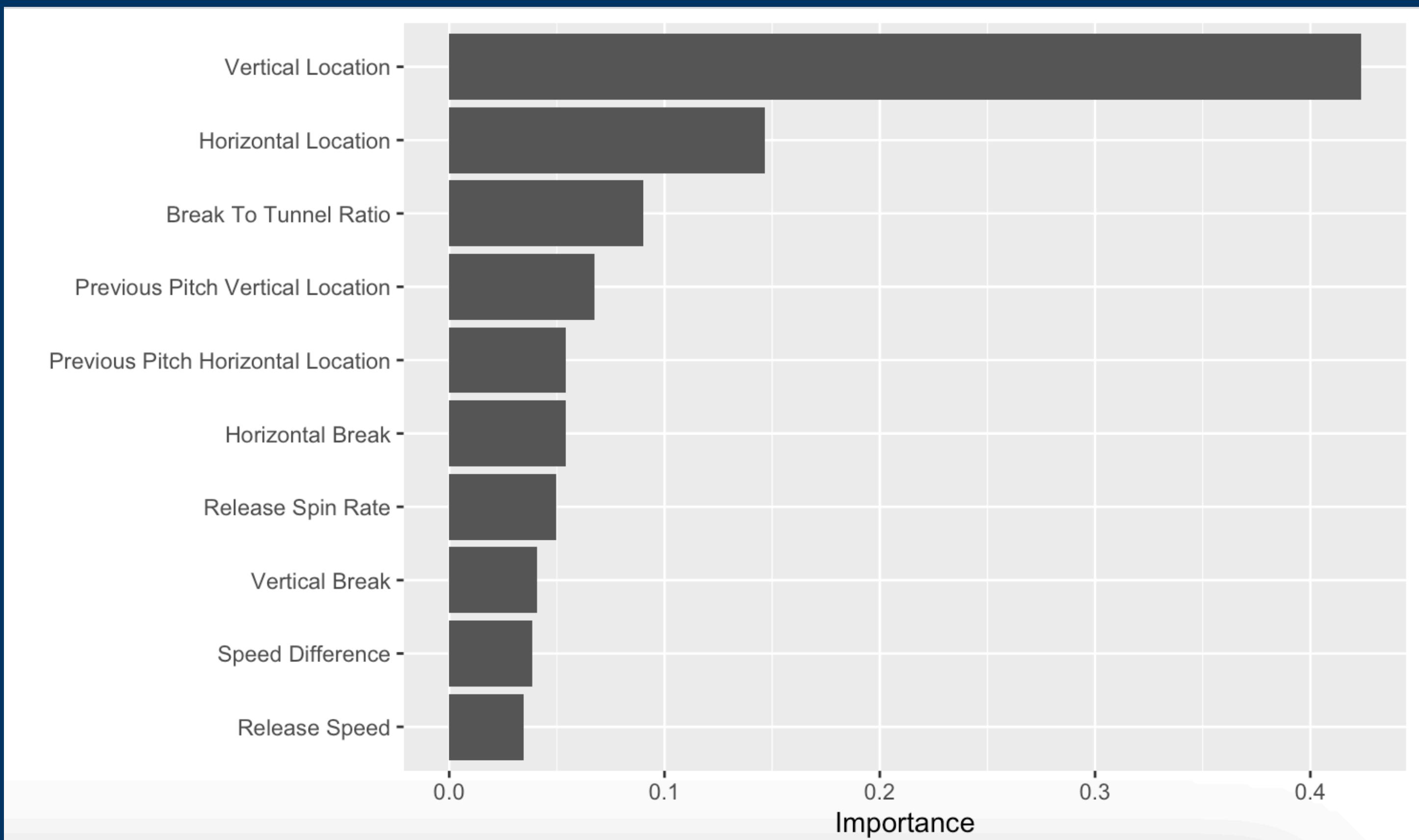


# Sinker -> Knuckle Curve | RHP -> RHH | Whiff

**Training Sample: n = 1008 pitches**

**Testing Sample: n = 434 pitches**

**Testing Accuracy: 76.04%**

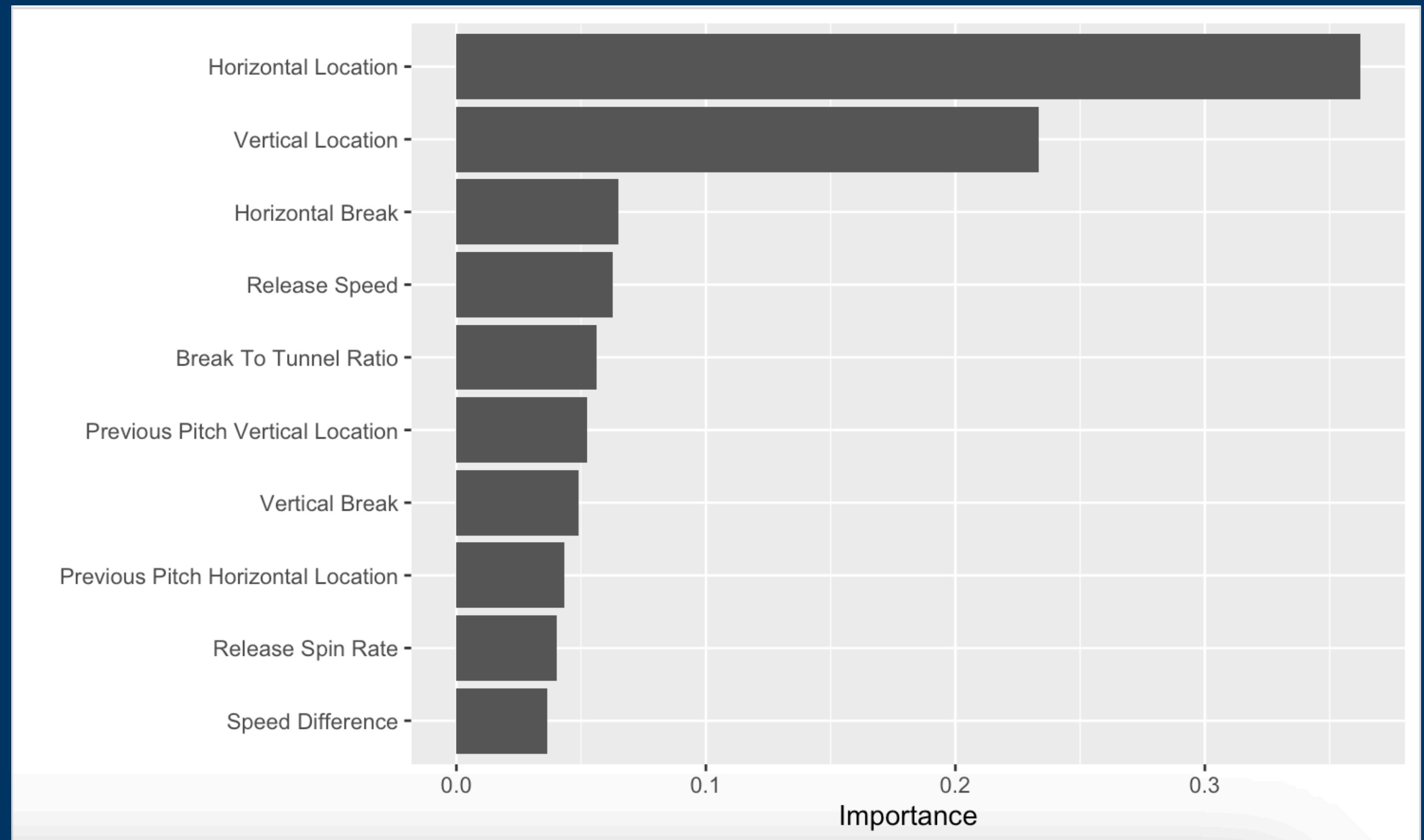


# Sinker -> Knuckle Curve | RHP -> RHH | Chase

**Training Sample: n = 1508 pitches**

**Testing Sample: n = 648 pitches**

**Testing Accuracy: 68.67%**

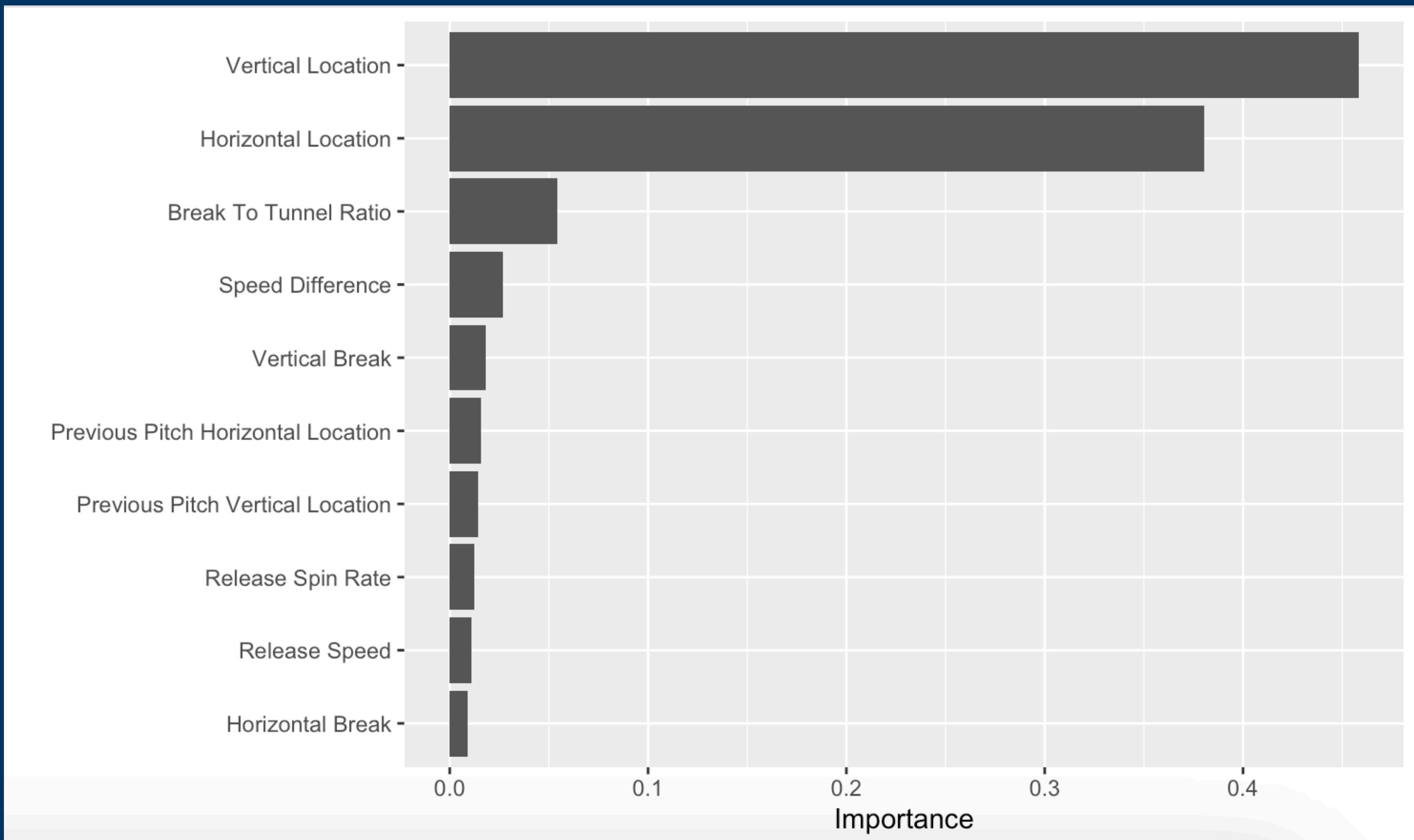


# Sinker -> Slider | RHP -> RHH | Whiff

**Training Sample: n = 13170 pitches**

**Testing Sample: n = 5646 pitches**

**Testing Accuracy: 70.81%**

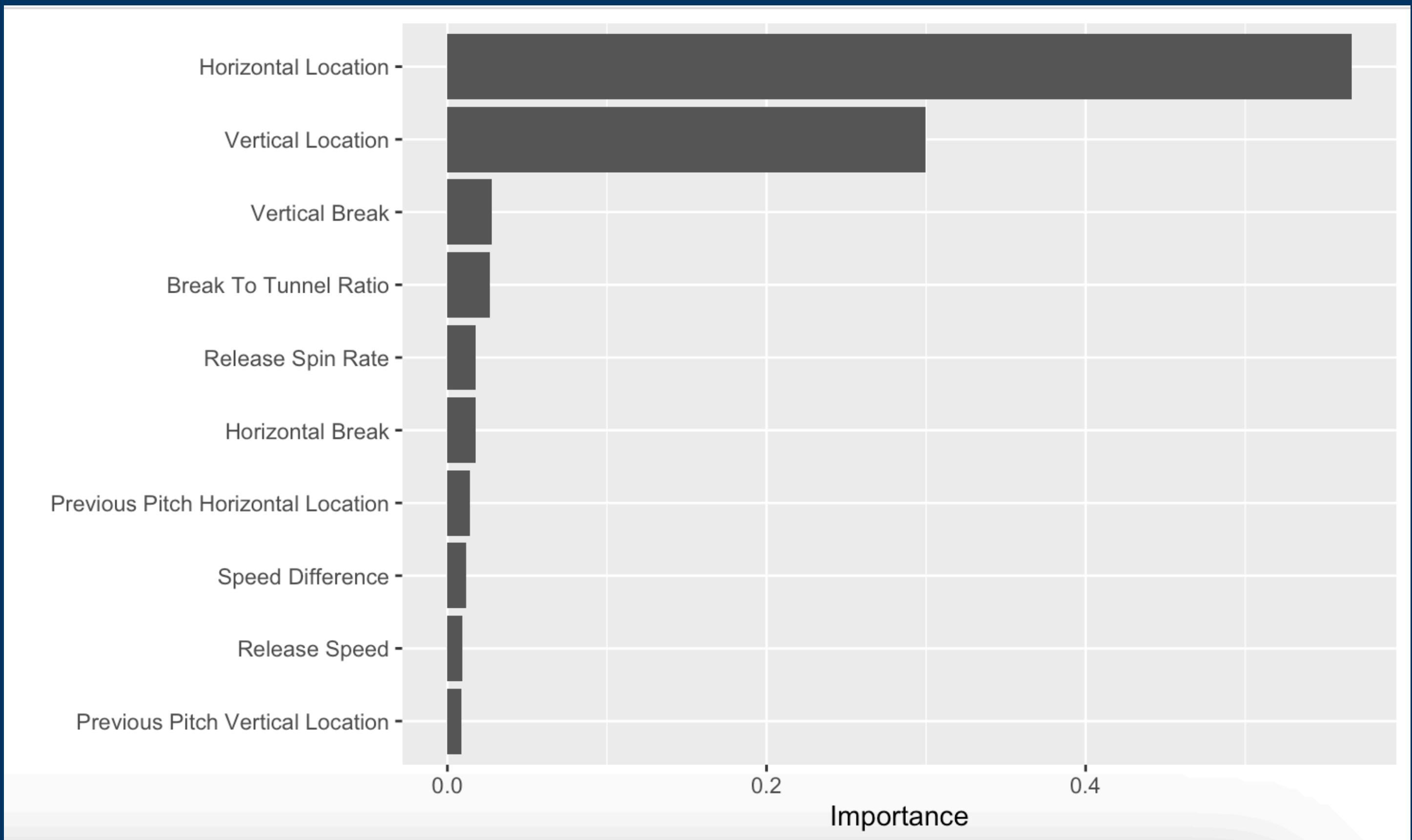


# Sinker -> Slider | RHP -> RHH | Chase

**Training Sample: n = 16516 pitches**

**Testing Sample: n = 7080 pitches**

**Testing Accuracy: 68.73%**

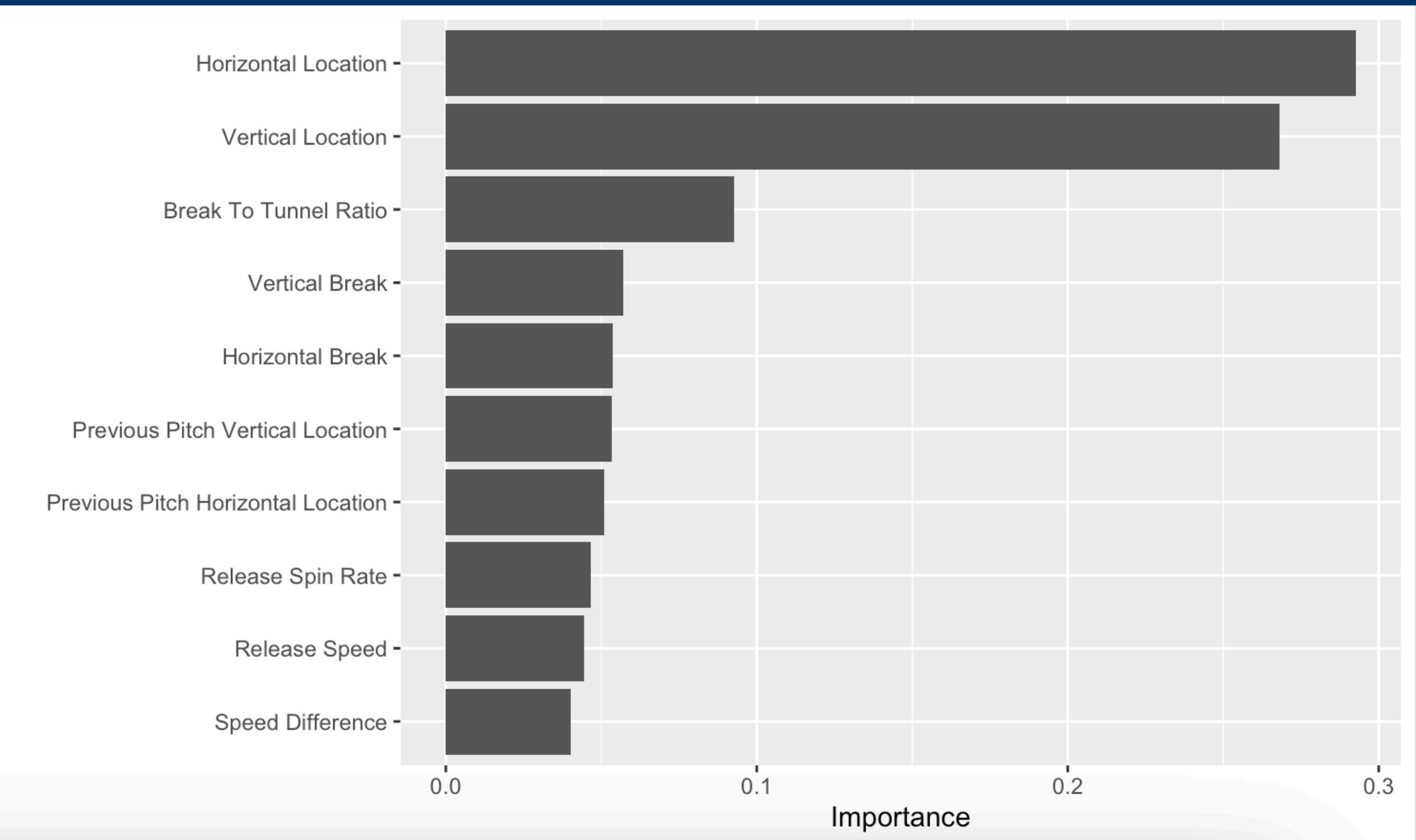


# Sinker -> Sweeper | RHP -> RHH | Whiff

**Training Sample: n = 1540 pitches**

**Testing Sample: n = 660 pitches**

**Testing Accuracy: 71.36%**

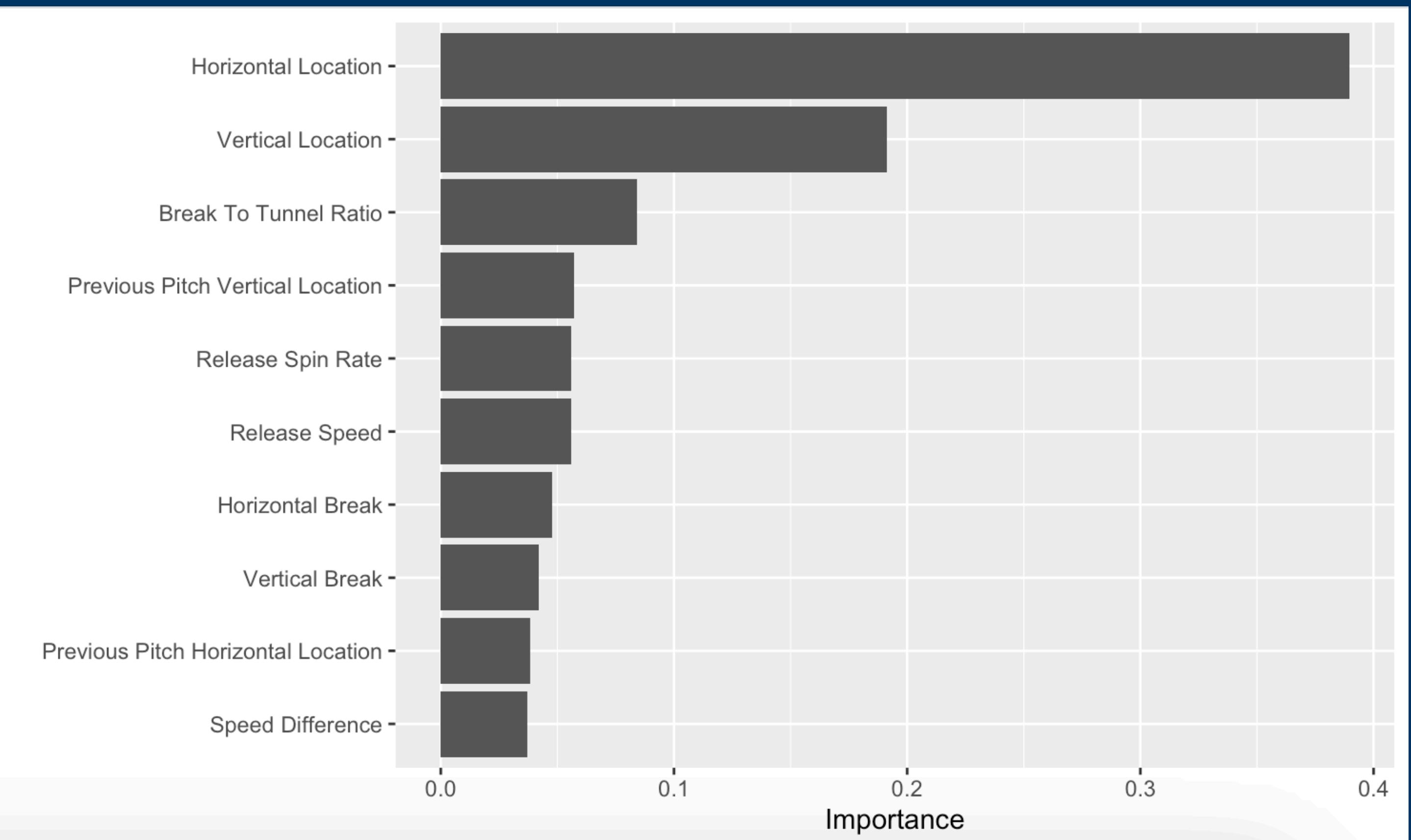


# Sinker -> Sweeper | RHP -> RHH | Chase

**Training Sample: n = 1878 pitches**

**Testing Sample: n = 806 pitches**

**Testing Accuracy: 68.61%**

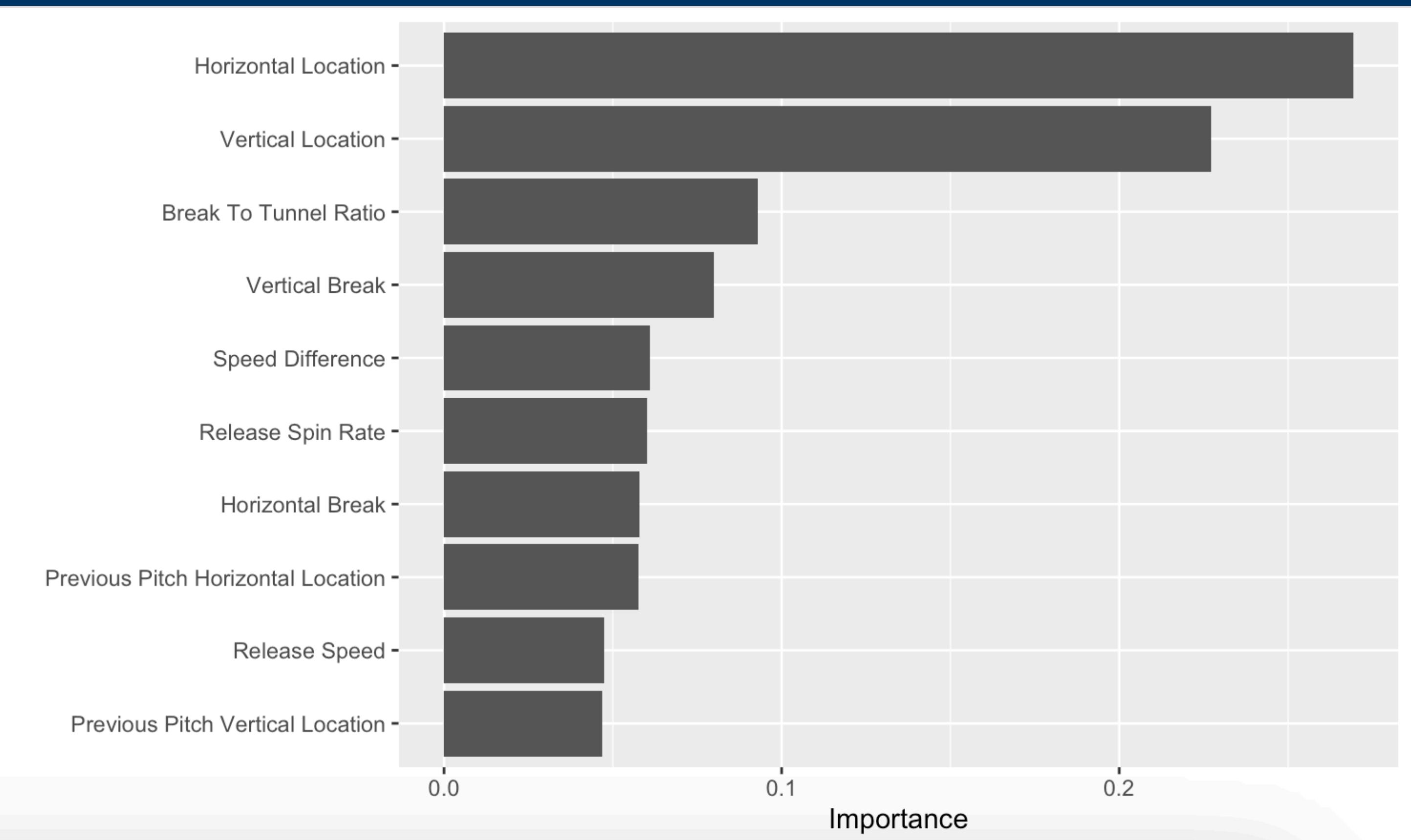


# Sinker -> Slurve | RHP -> RHH | Whiff

**Training Sample: n = 400 pitches**

**Testing Sample: n = 172 pitches**

**Testing Accuracy: 73.84%**

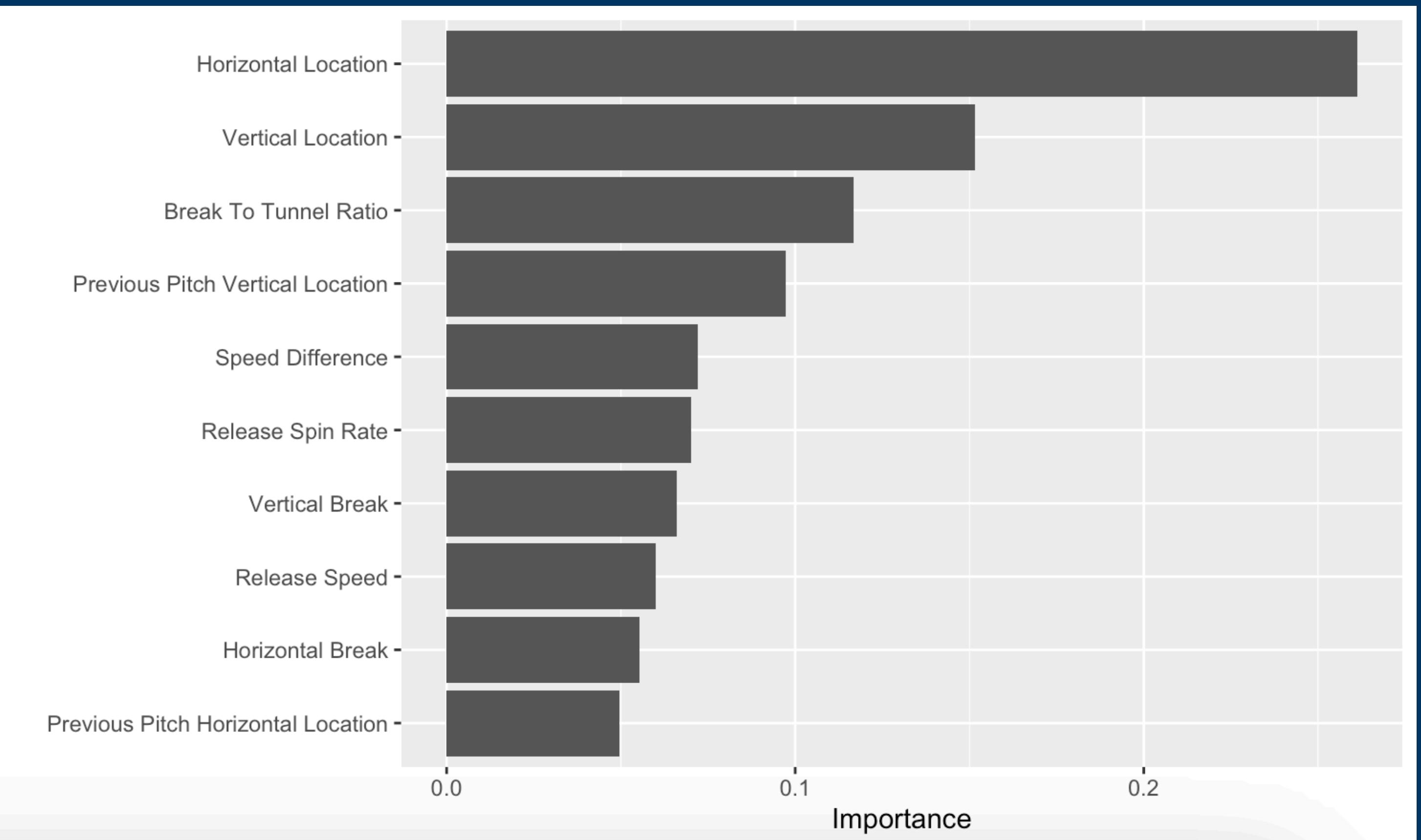


# Sinker -> Slurve | RHP -> RHH | Chase

**Training Sample: n = 610 pitches**

**Testing Sample: n = 262 pitches**

**Testing Accuracy: 73.84%**



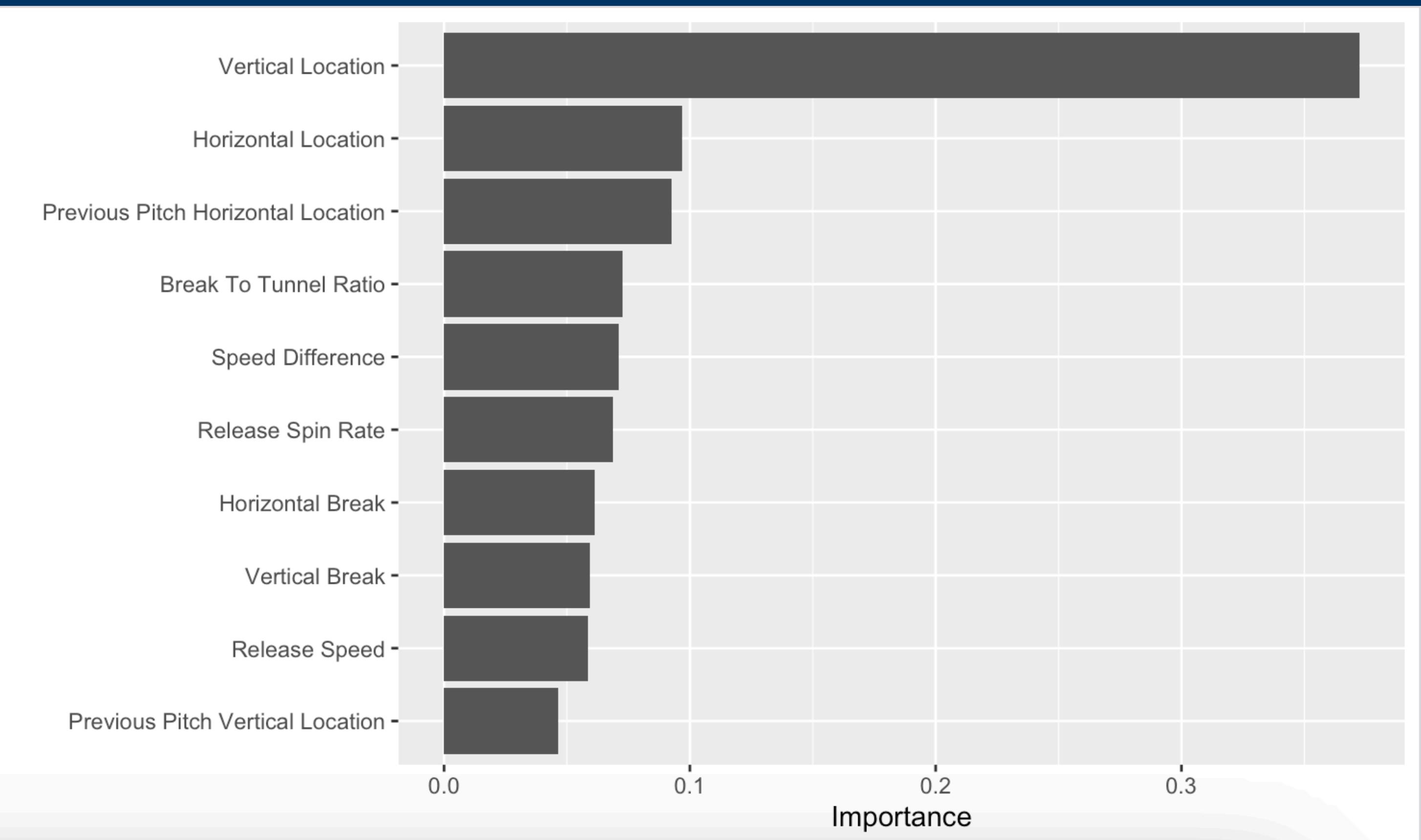
# Right Handed Pitchers vs Left Handed Hitters

# Cutter -> Changeup | RHP -> LHH | Whiff

**Training Sample: n = 2156 pitches**

**Testing Sample: n = 926 pitches**

**Testing Accuracy: 65.12%**

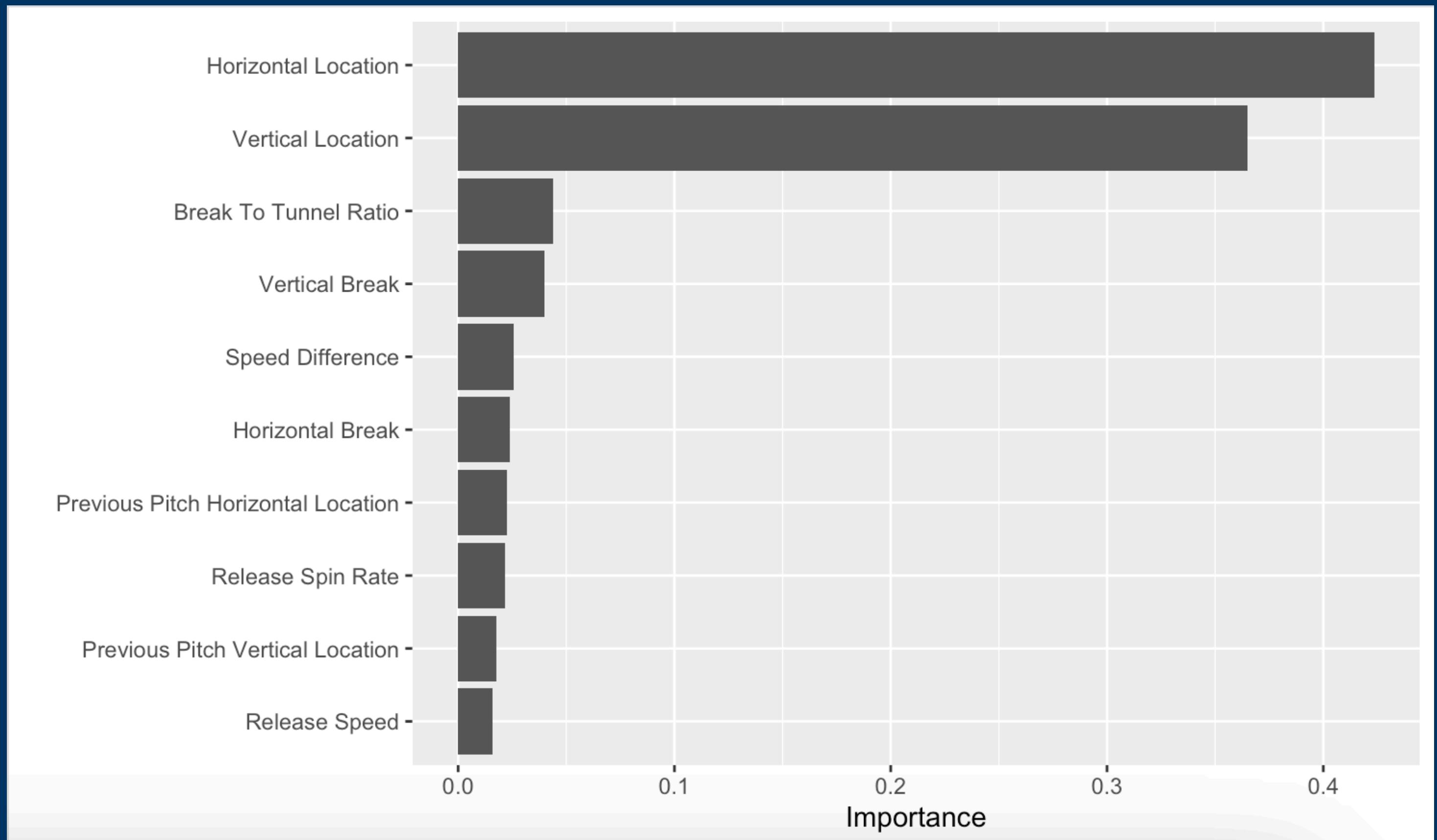


# Cutter -> Changeup | RHP -> LHH | Chase

**Training Sample: n = 3904 pitches**

**Testing Sample: n = 1674 pitches**

**Testing Accuracy: 74.49%**

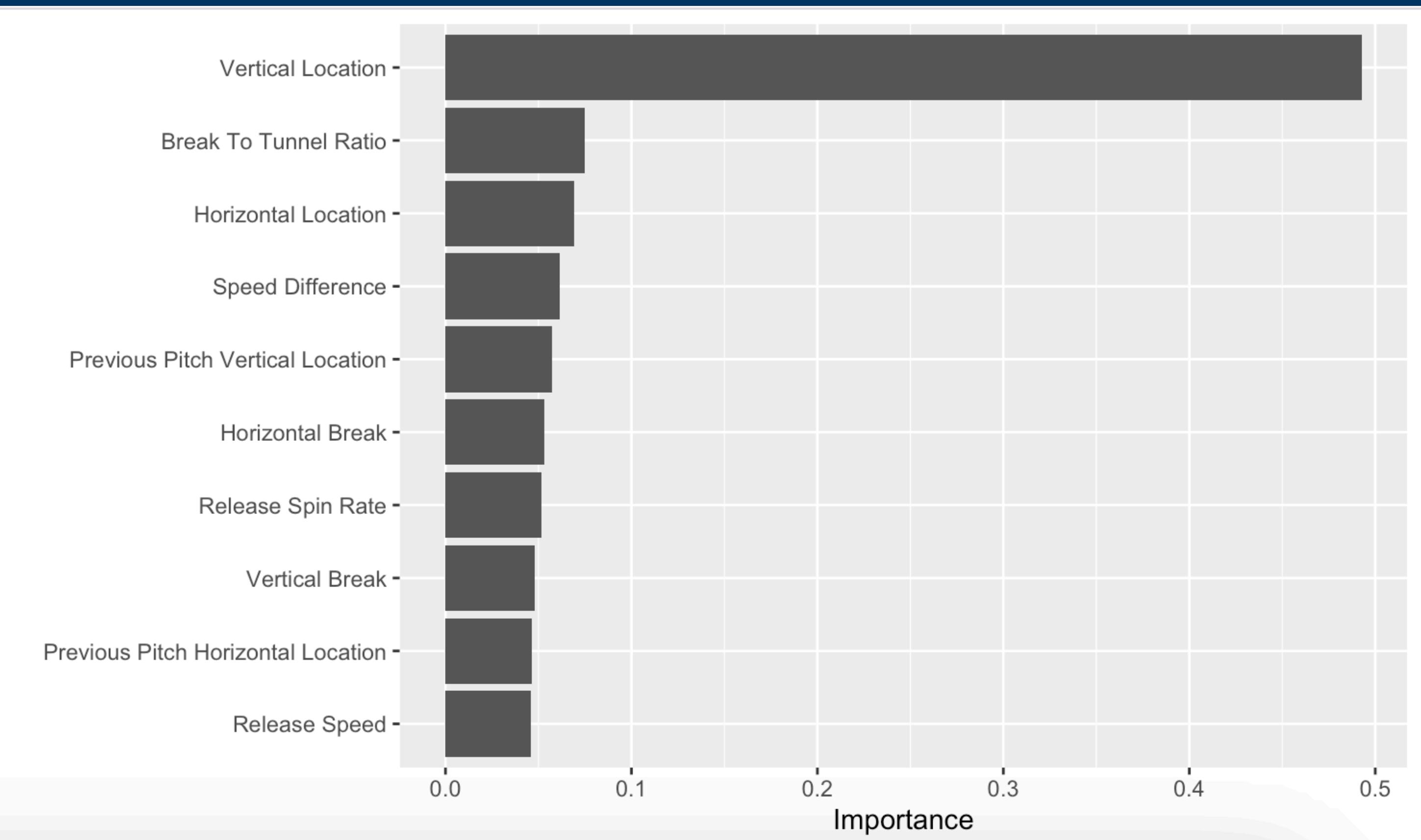


# Cutter -> Curveball | RHP -> LHH | Whiff

**Training Sample: n = 1590 pitches**

**Testing Sample: n = 684 pitches**

**Testing Accuracy: 71.20%**

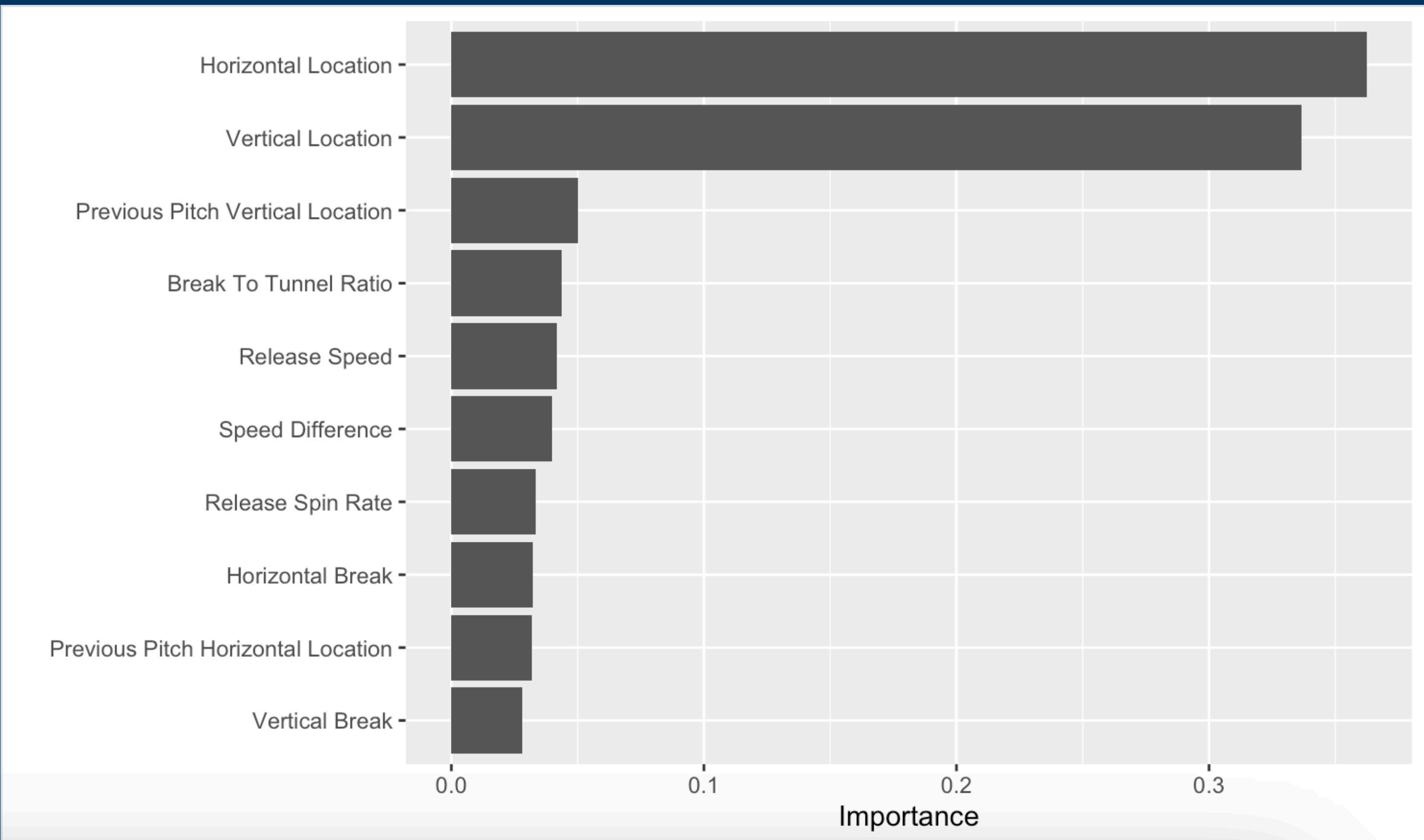


# Cutter -> Curveball | RHP -> LHH | Chase

**Training Sample: n = 2352 pitches**

**Testing Sample: n = 1008 pitches**

**Testing Accuracy: 72.22%**

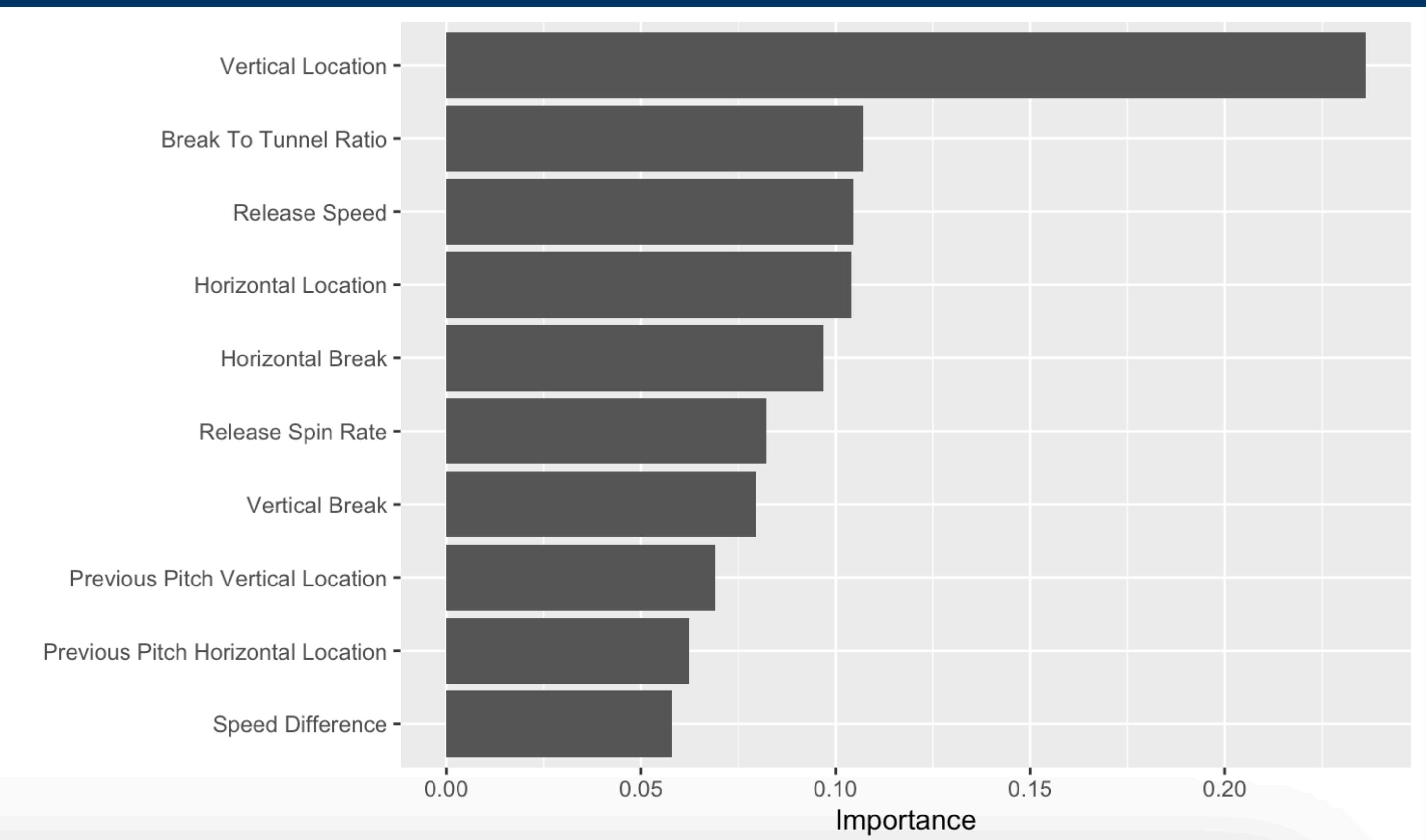


# Cutter -> Splitter | RHP -> LHH | Whiff

**Training Sample: n = 418 pitches**

**Testing Sample: n = 180 pitches**

**Testing Accuracy: 63.33%**

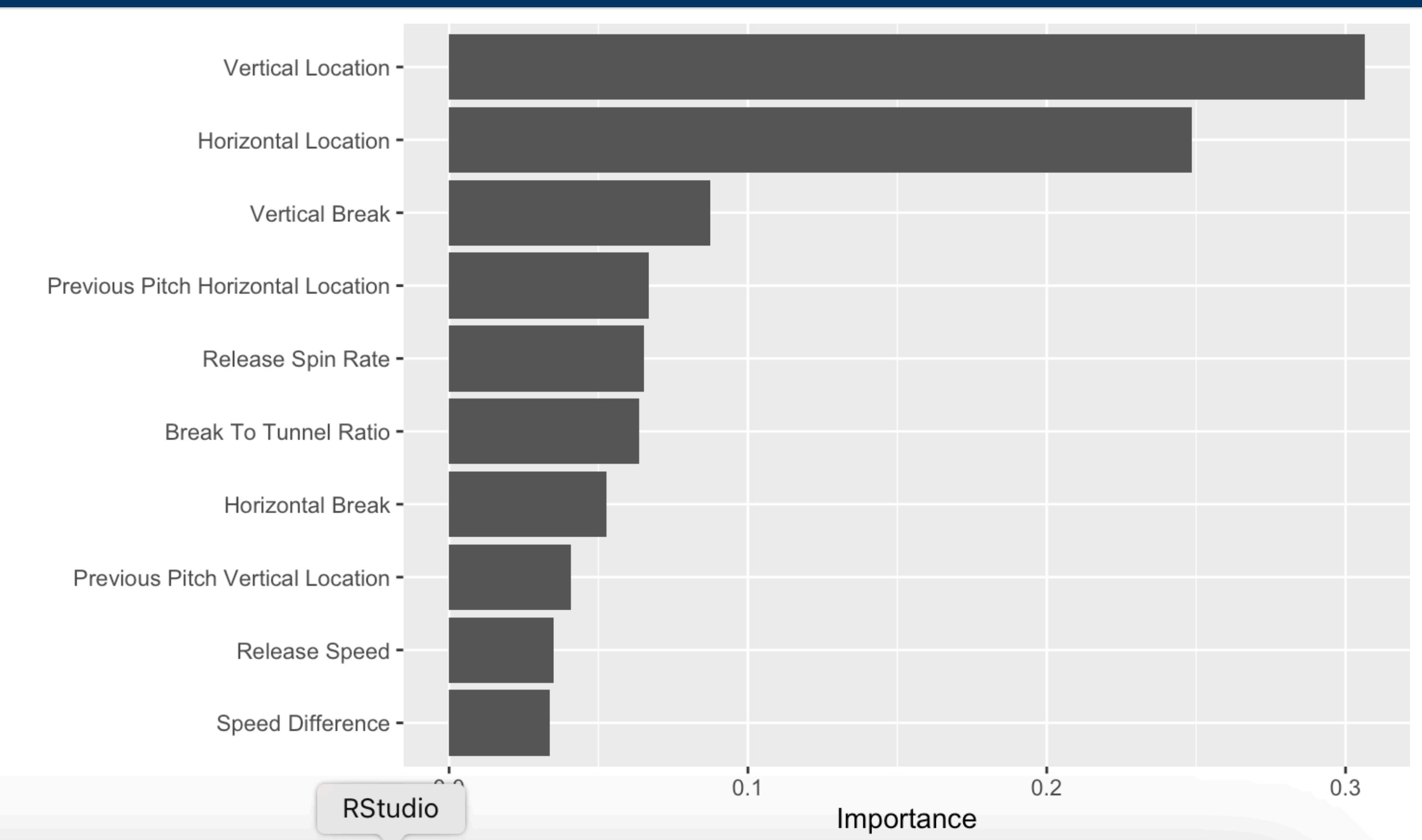


# Cutter -> Splitter | RHP -> LHH | Chase

**Training Sample: n = 708 pitches**

**Testing Sample: n = 304 pitches**

**Testing Accuracy: 69.41%**

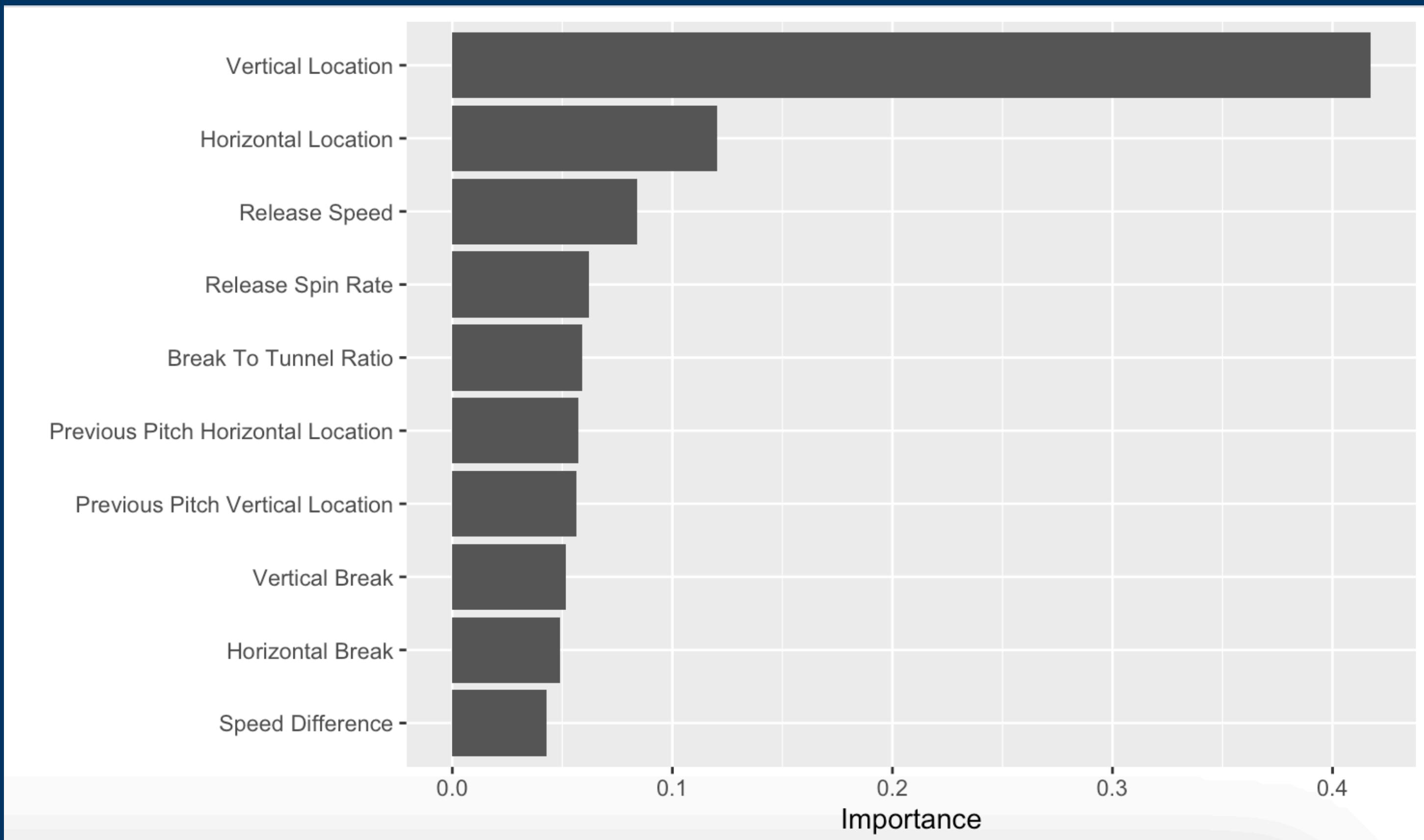


# Cutter -> Knuckle Curve | RHP -> LHH | Whiff

**Training Sample: n = 726 pitches**

**Testing Sample: n = 312 pitches**

**Testing Accuracy: 74.04%**

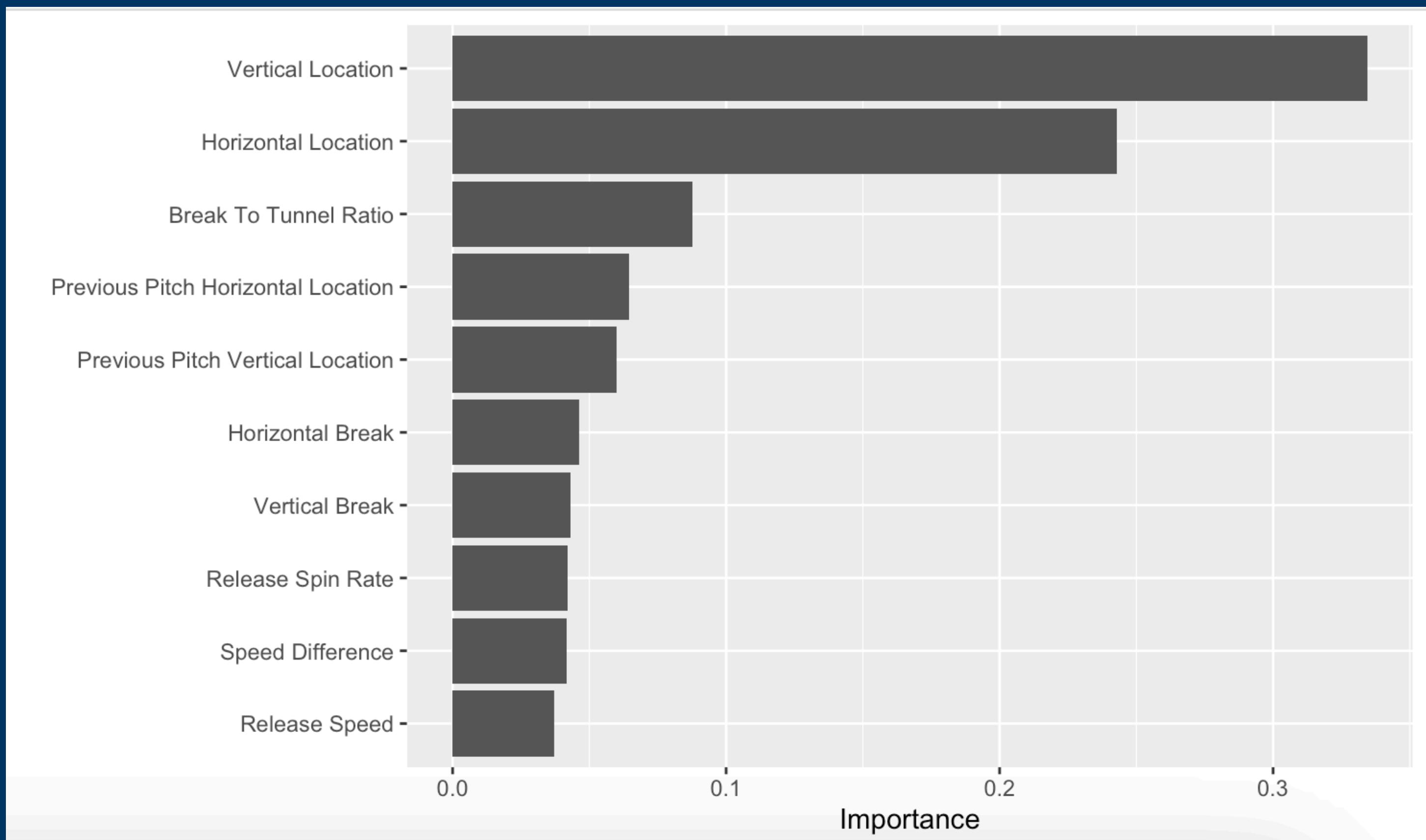


# Cutter -> Knuckle Curve | RHP -> LHH | Chase

**Training Sample: n = 1006 pitches**

**Testing Sample: n = 434 pitches**

**Testing Accuracy: 69.59%**

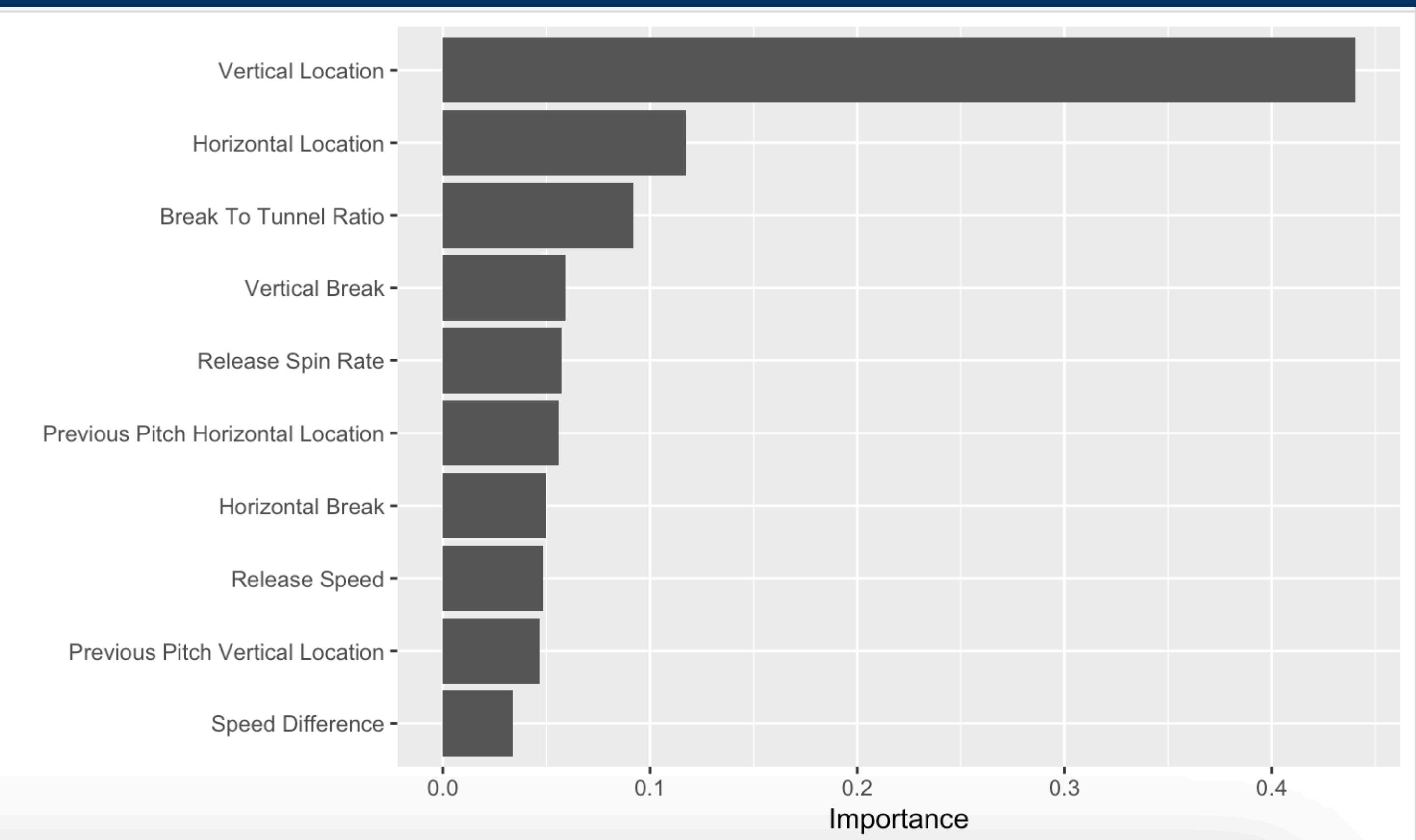


# Cutter -> Slider | RHP -> LHH | Whiff

**Training Sample: n = 988 pitches**

**Testing Sample: n = 424 pitches**

**Testing Accuracy: 71.46%**

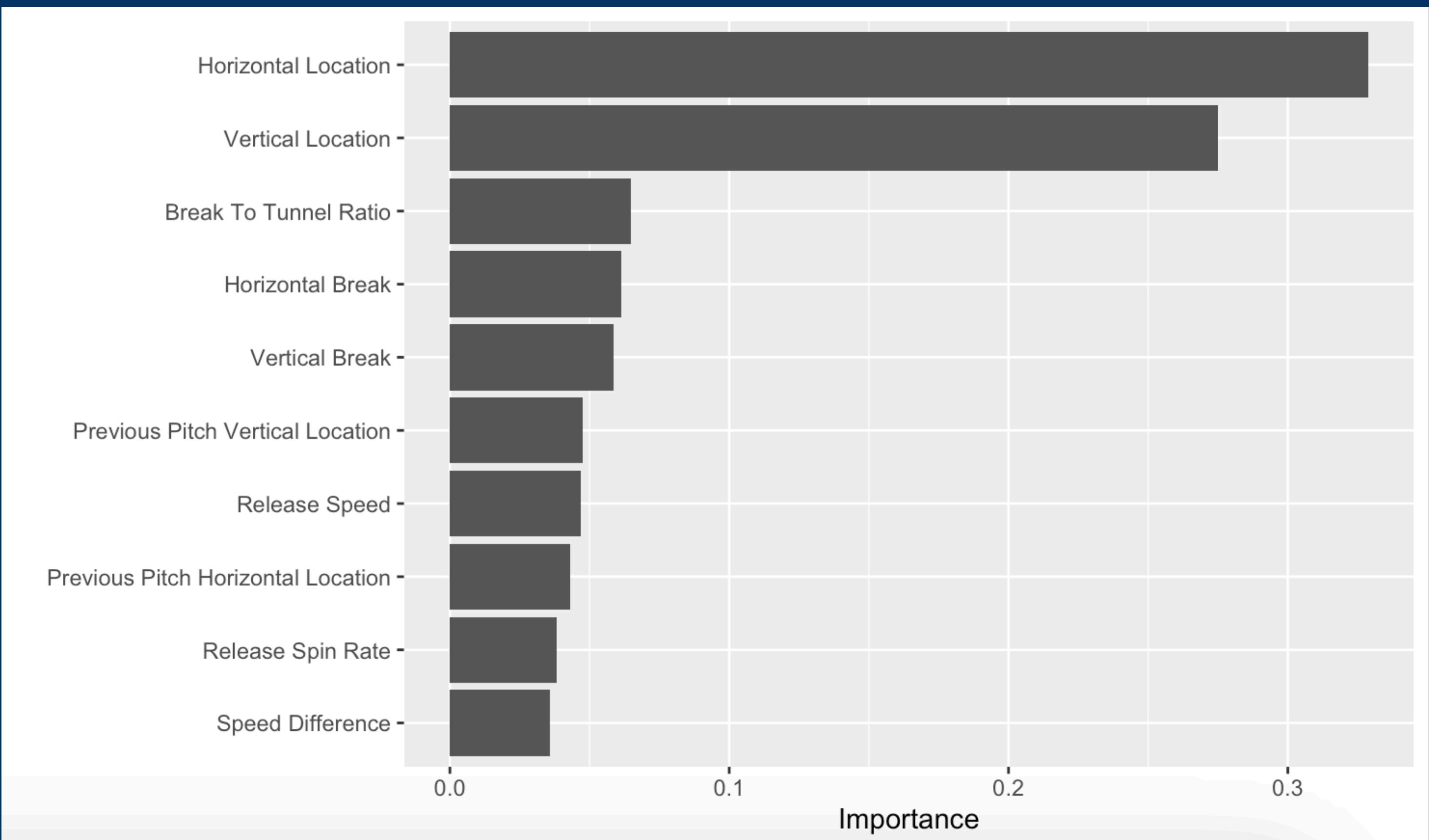


# Cutter -> Slider | RHP -> LHH | Chase

**Training Sample: n = 1438 pitches**

**Testing Sample: n = 618 pitches**

**Testing Accuracy: 70.87%**

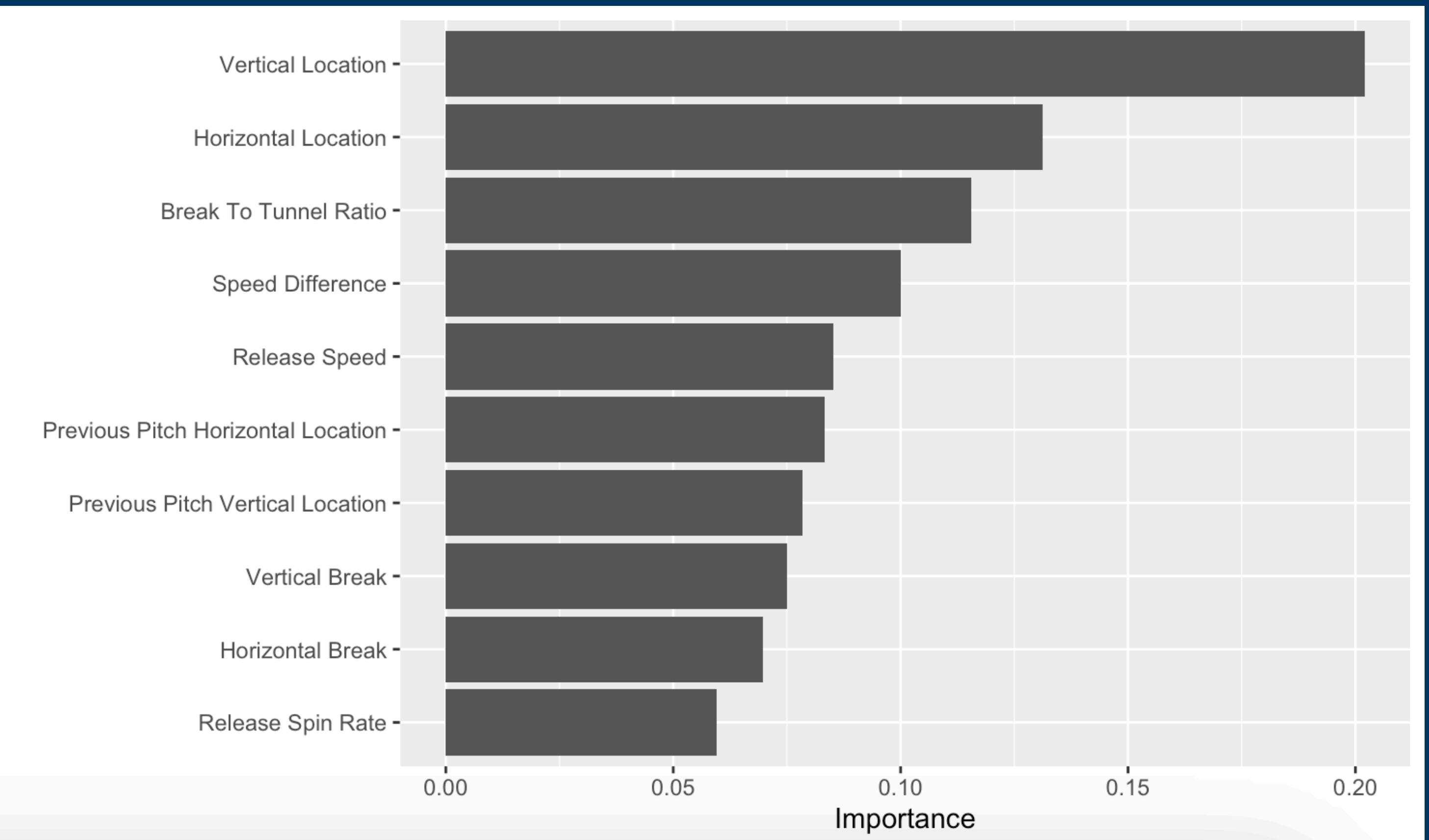


# Cutter -> Sweeper | RHP -> LHH | Whiff

**Training Sample: n = 248 pitches**

**Testing Sample: n = 108 pitches**

**Testing Accuracy: 65.74%**

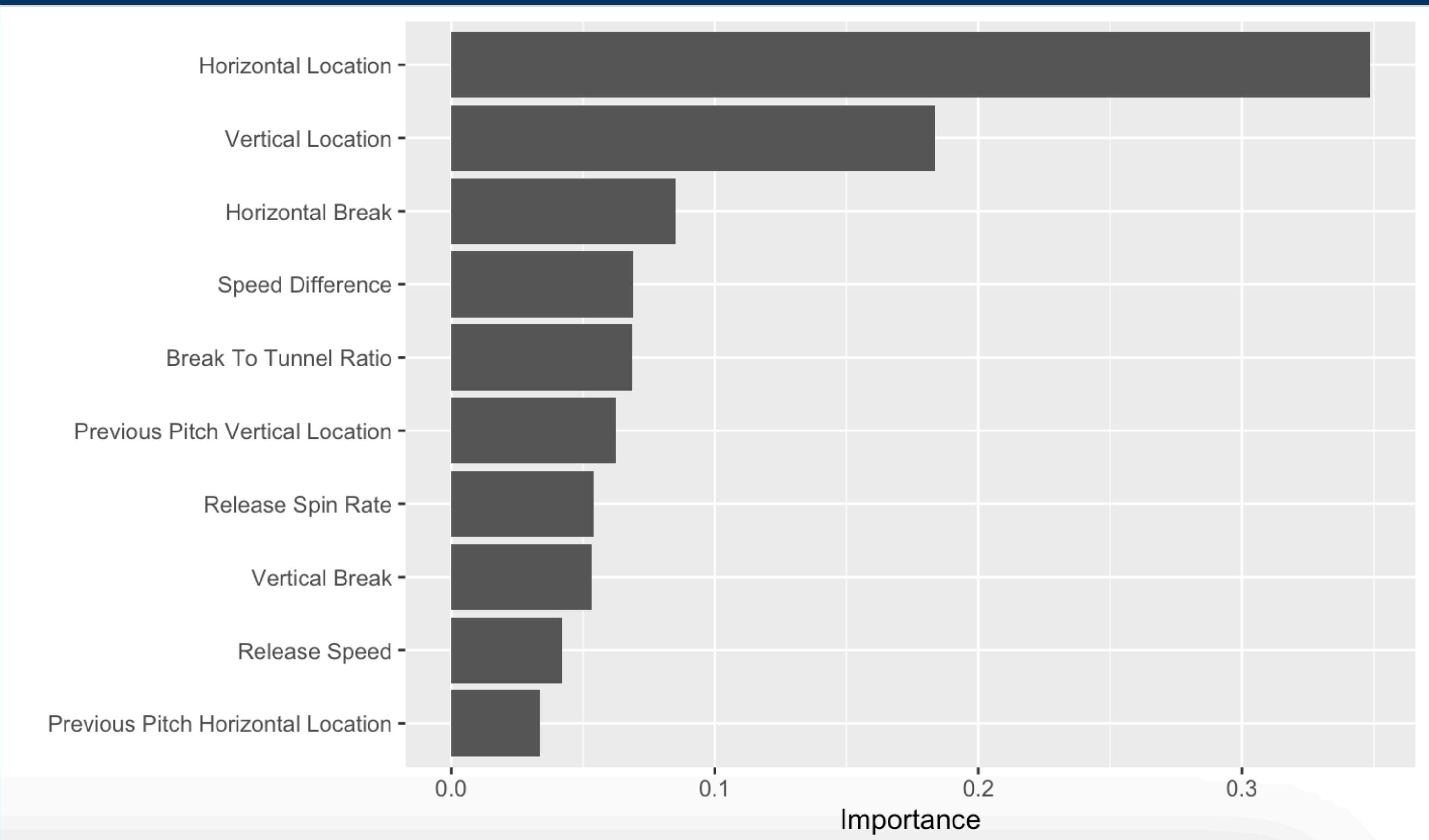


# Cutter -> Sweeper | RHP -> LHH | Chase

**Training Sample: n = 360 pitches**

**Testing Sample: n = 156 pitches**

**Testing Accuracy: 76.28%**

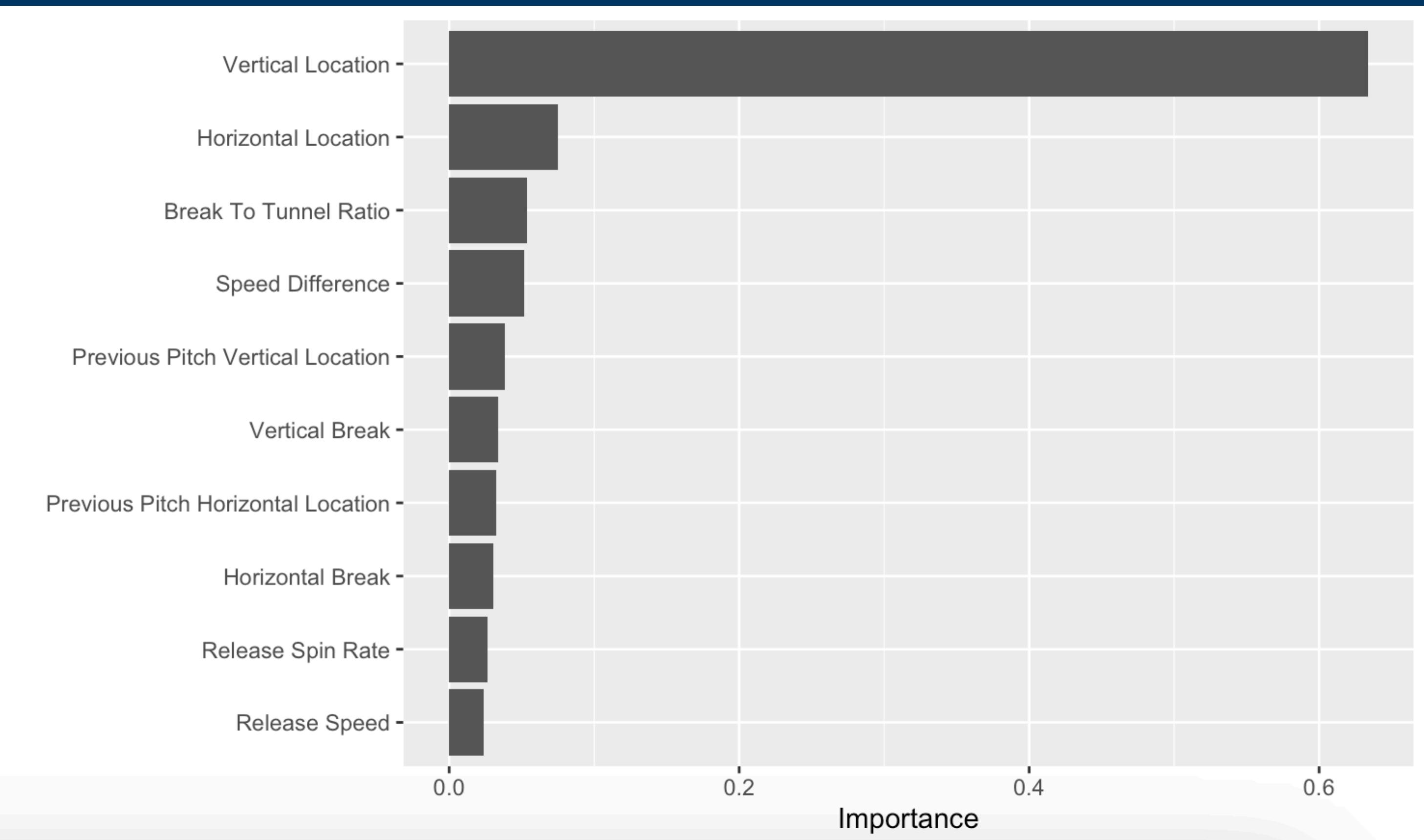


# Four-Seam -> Changeup | RHP -> LHH | Whiff

**Training Sample: n = 15296 pitches**

**Testing Sample: n = 6558 pitches**

**Testing Accuracy: 64.44%**

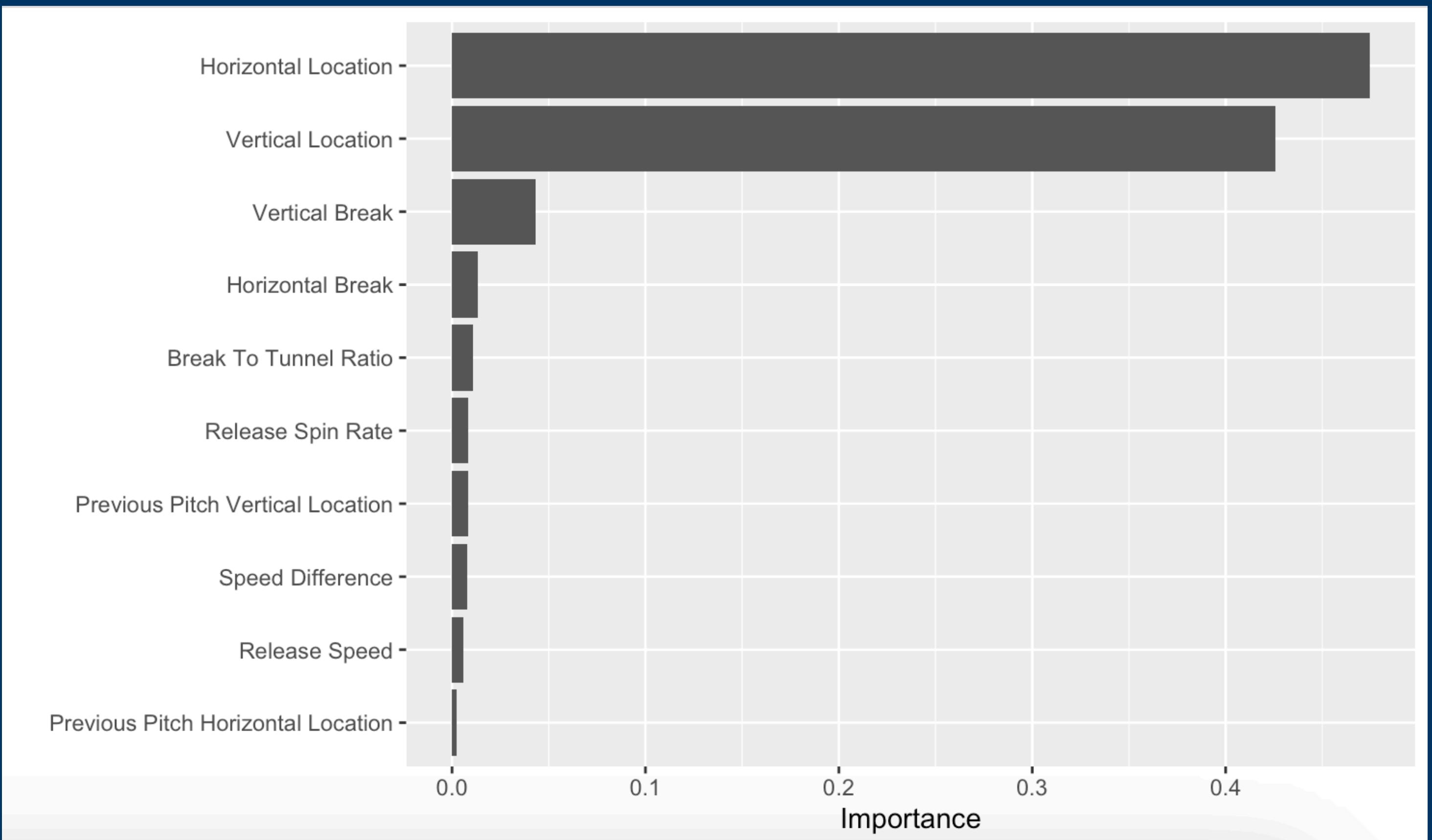


# Four-Seam -> Changeup | RHP -> LHH | Chase

**Training Sample: n = 26566 pitches**

**Testing Sample: n = 11386 pitches**

**Testing Accuracy: 73.22%**

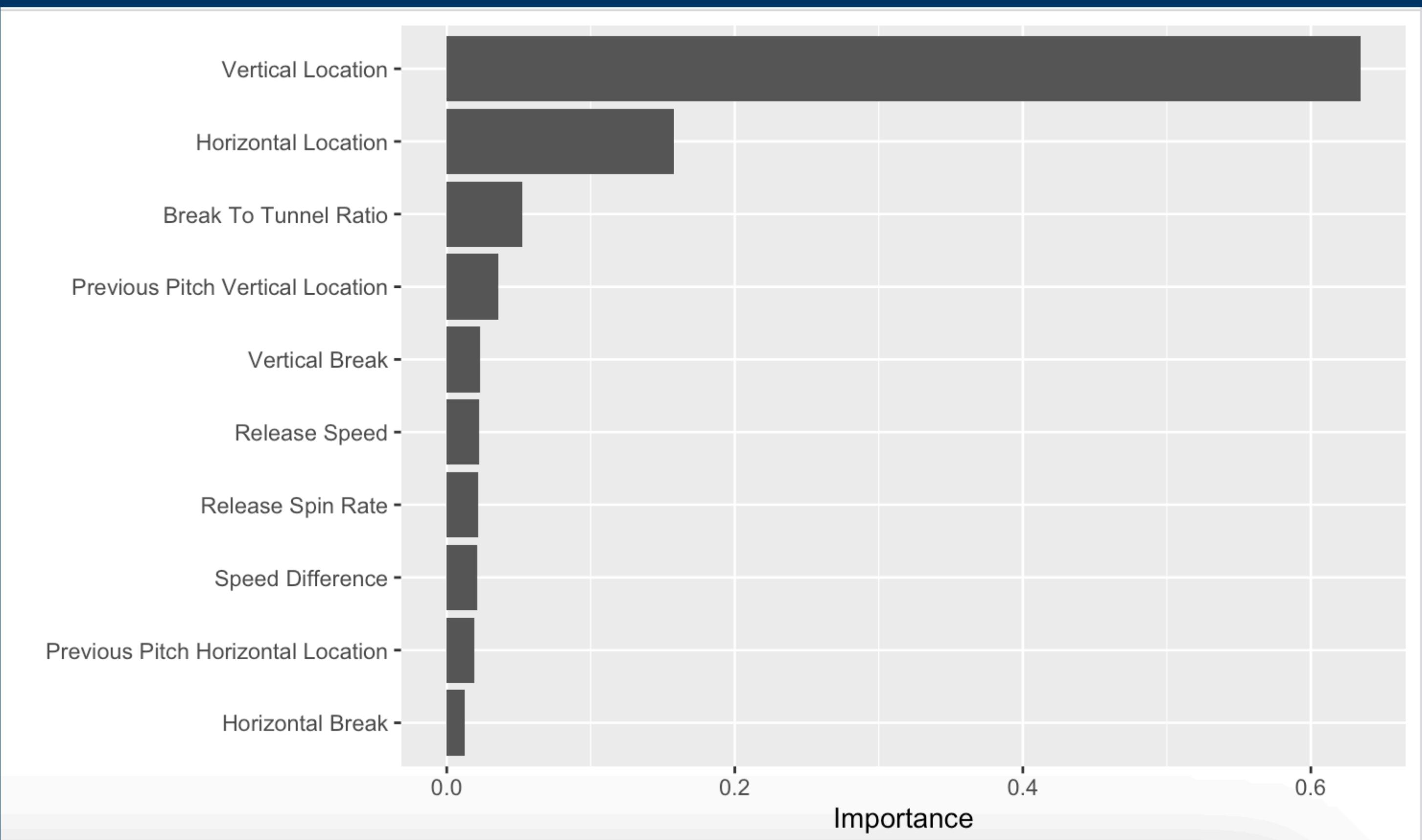


# Four-Seam -> Curveball | RHP -> LHH | Whiff

**Training Sample: n = 7766 pitches**

**Testing Sample: n = 3330 pitches**

**Testing Accuracy: 71.35%**

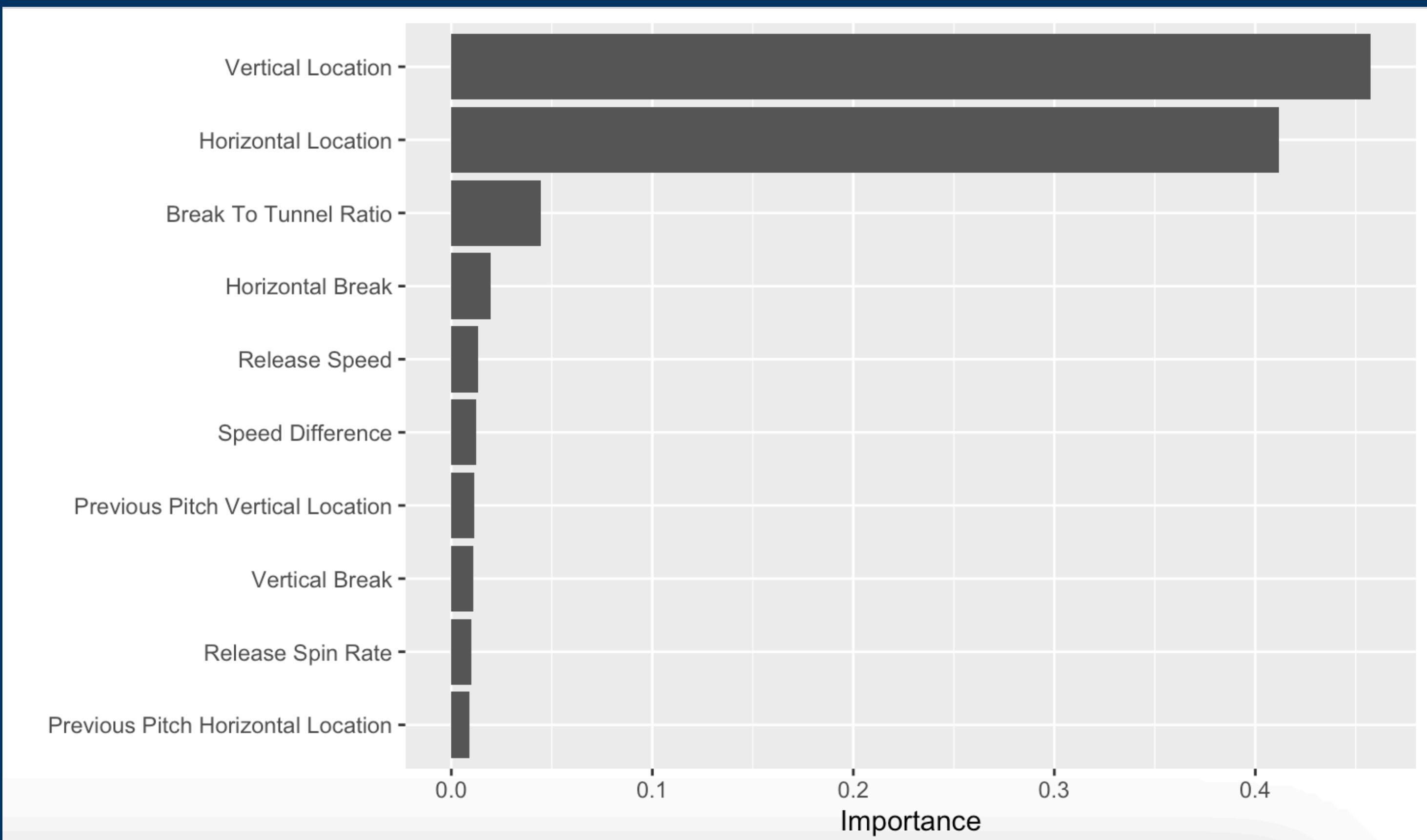


# Four-Seam -> Curveball | RHP -> LHH | Chase

**Training Sample: n = 12256 pitches**

**Testing Sample: n = 5254 pitches**

**Testing Accuracy: 71.85%**

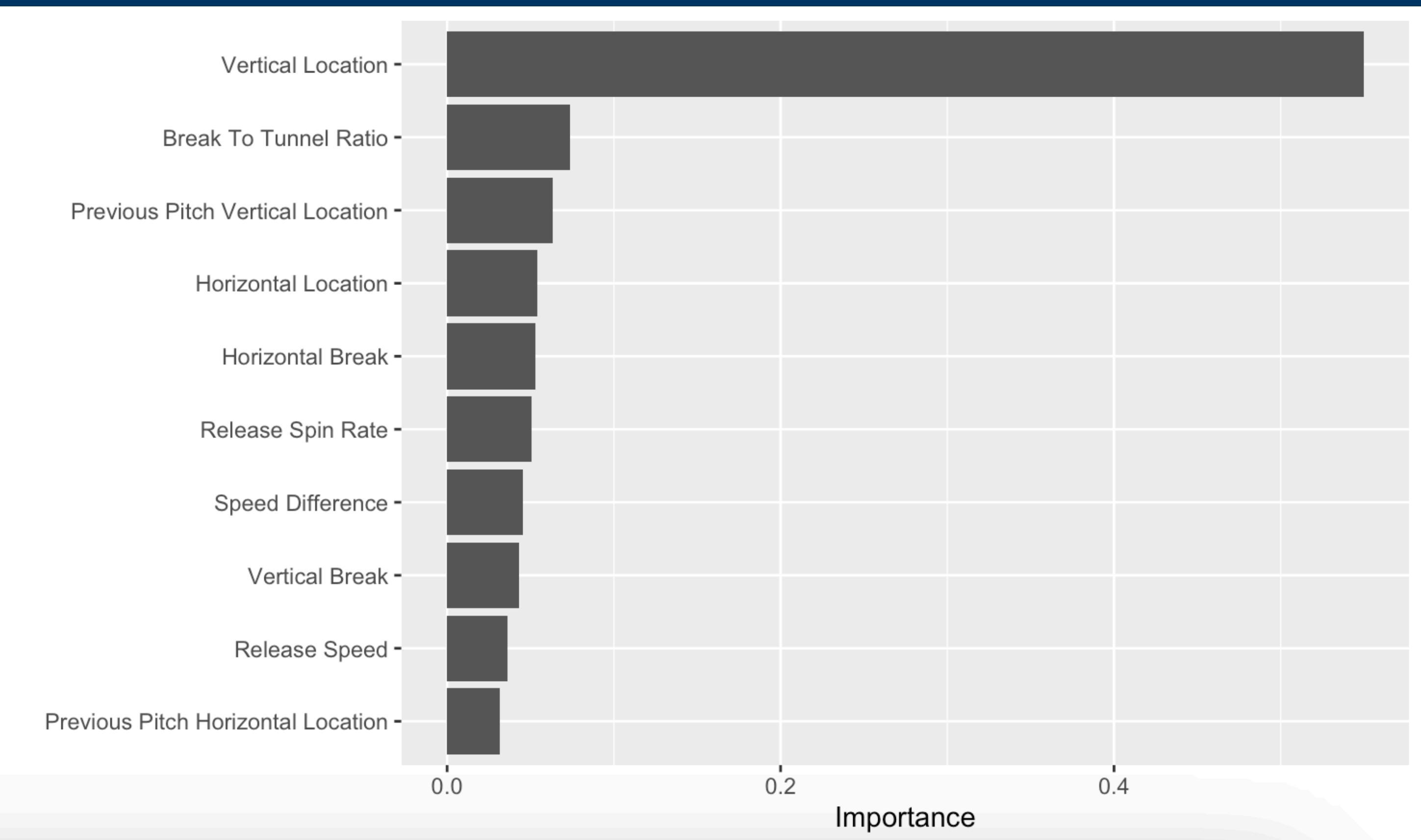


# Four-Seam -> Splitter | RHP -> LHH | Whiff

**Training Sample: n = 3634 pitches**

**Testing Sample: n = 1558 pitches**

**Testing Accuracy: 68.42%**

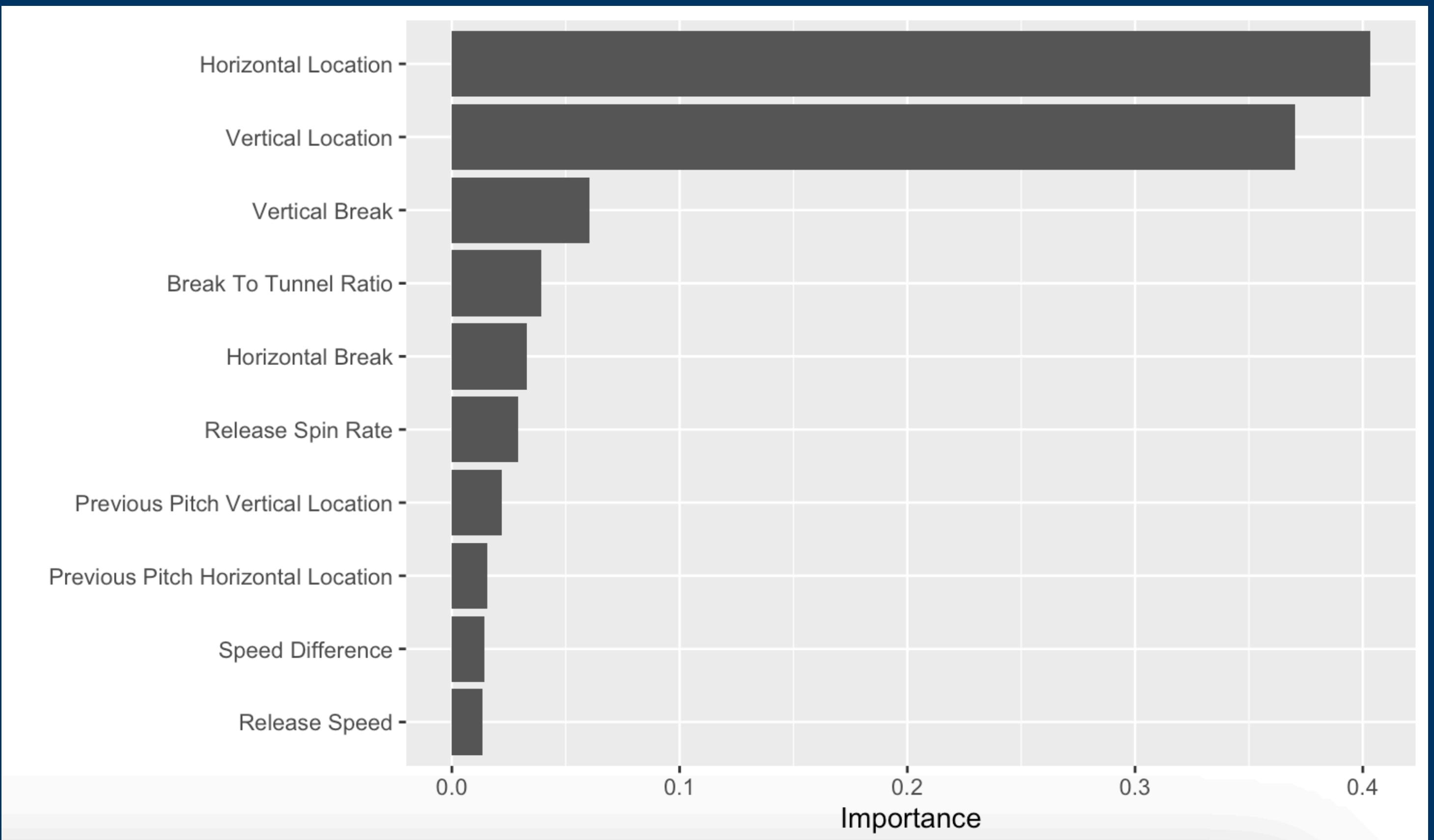


# Four-Seam -> Splitter | RHP -> LHH | Chase

**Training Sample: n = 6028 pitches**

**Testing Sample: n = 2586 pitches**

**Testing Accuracy: 73.36%**

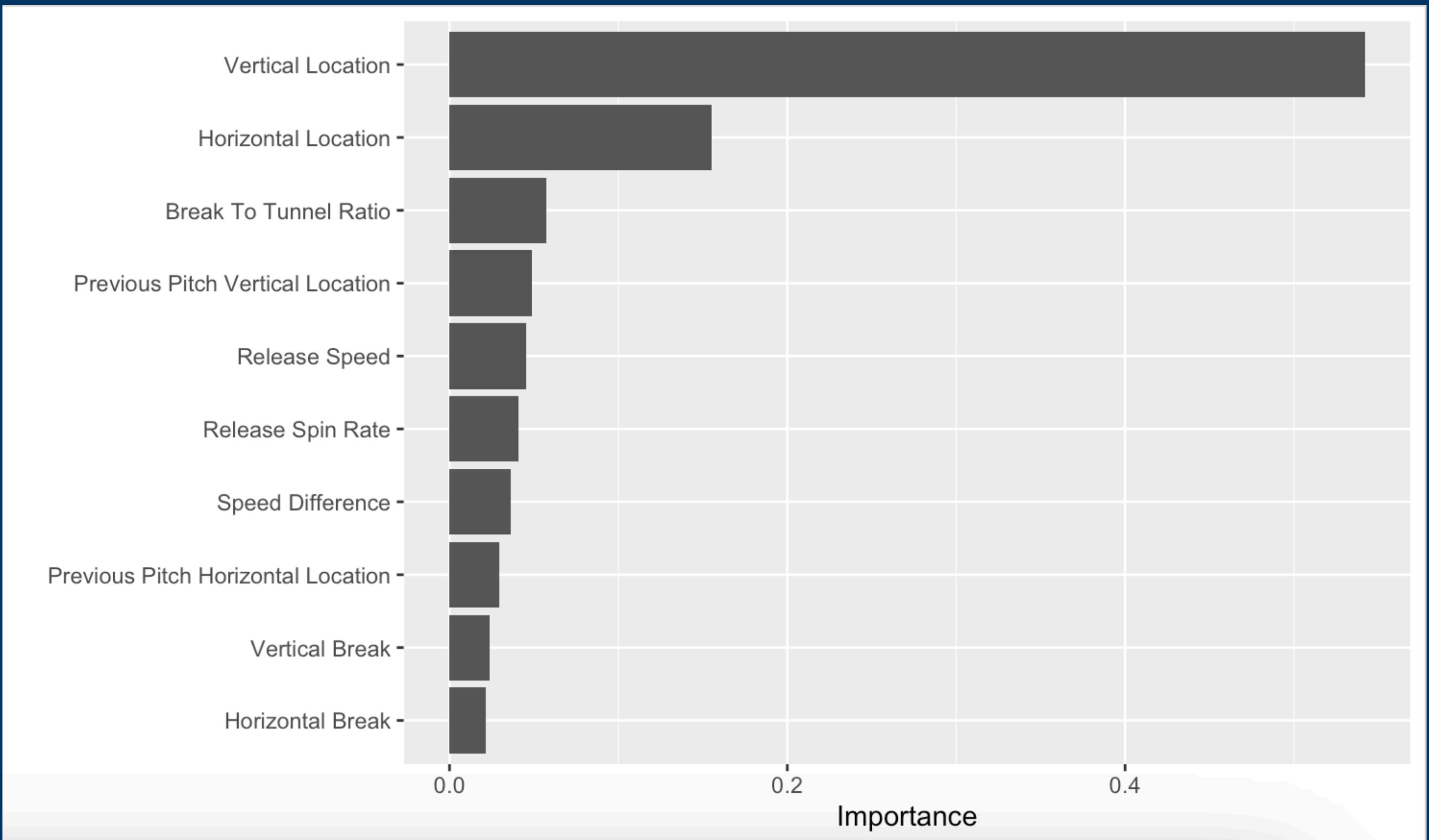


# Four-Seam -> Knuckle Curve | RHP -> LHH | Whiff

**Training Sample: n = 2982 pitches**

**Testing Sample: n = 1280 pitches**

**Testing Accuracy: 75.23%**

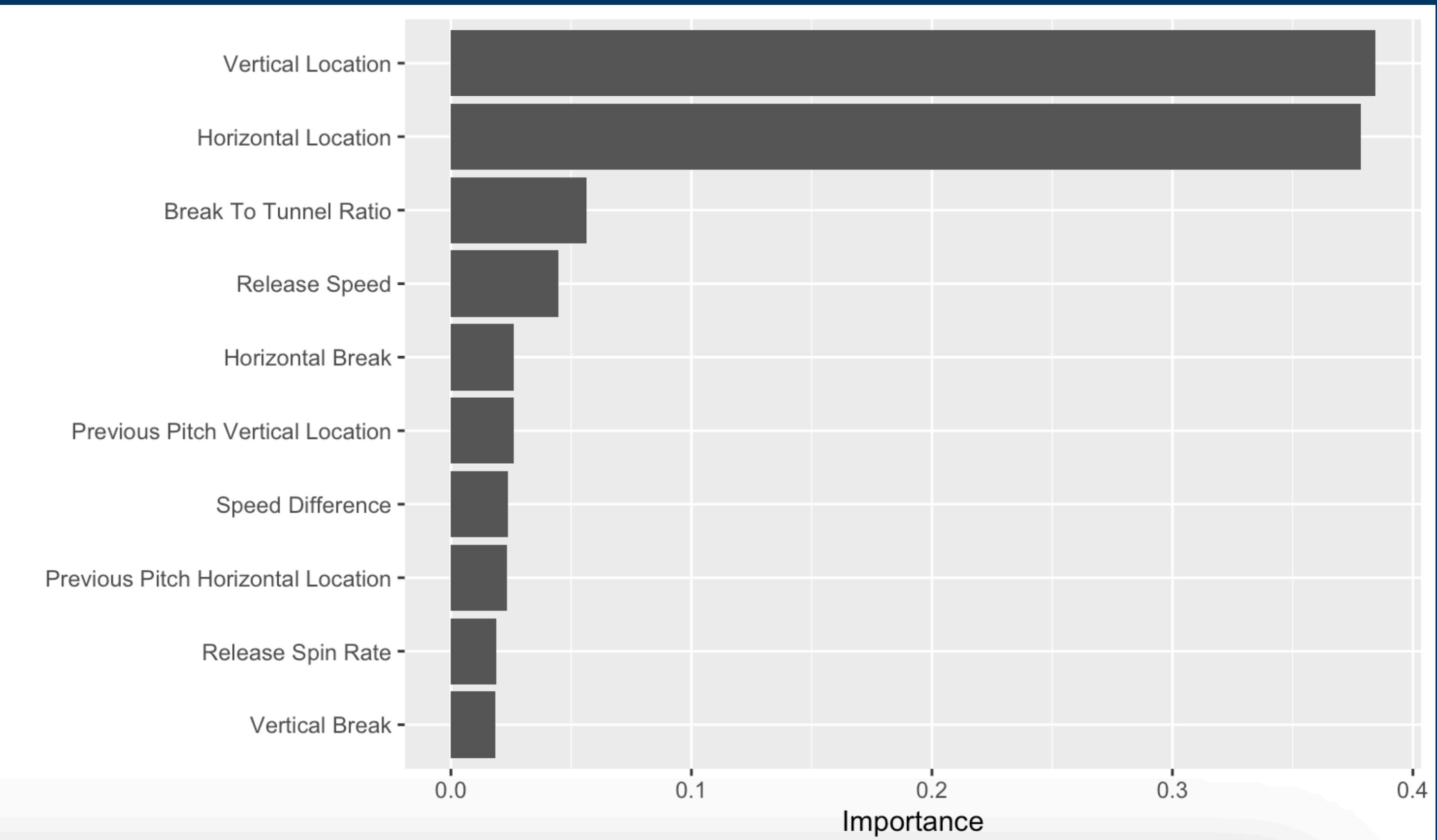


# Four-Seam -> Knuckle Curve | RHP -> LHH | Chase

**Training Sample: n = 4360 pitches**

**Testing Sample: n = 1870 pitches**

**Testing Accuracy: 70.64%**

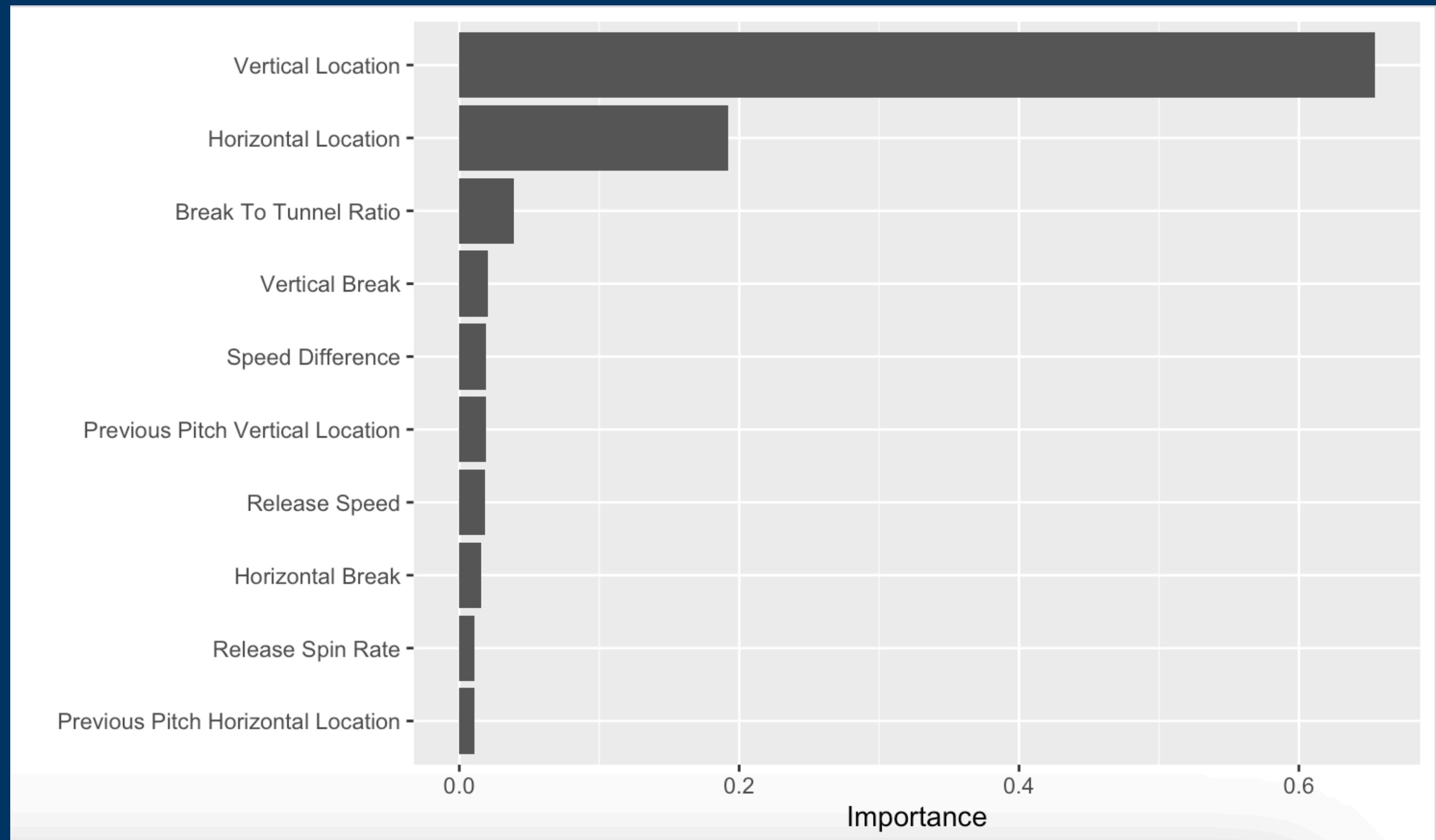


# Four-Seam -> Slider | RHP -> LHH | Whiff

**Training Sample: n = 13032 pitches**

**Testing Sample: n = 5586 pitches**

**Testing Accuracy: 71.84%**

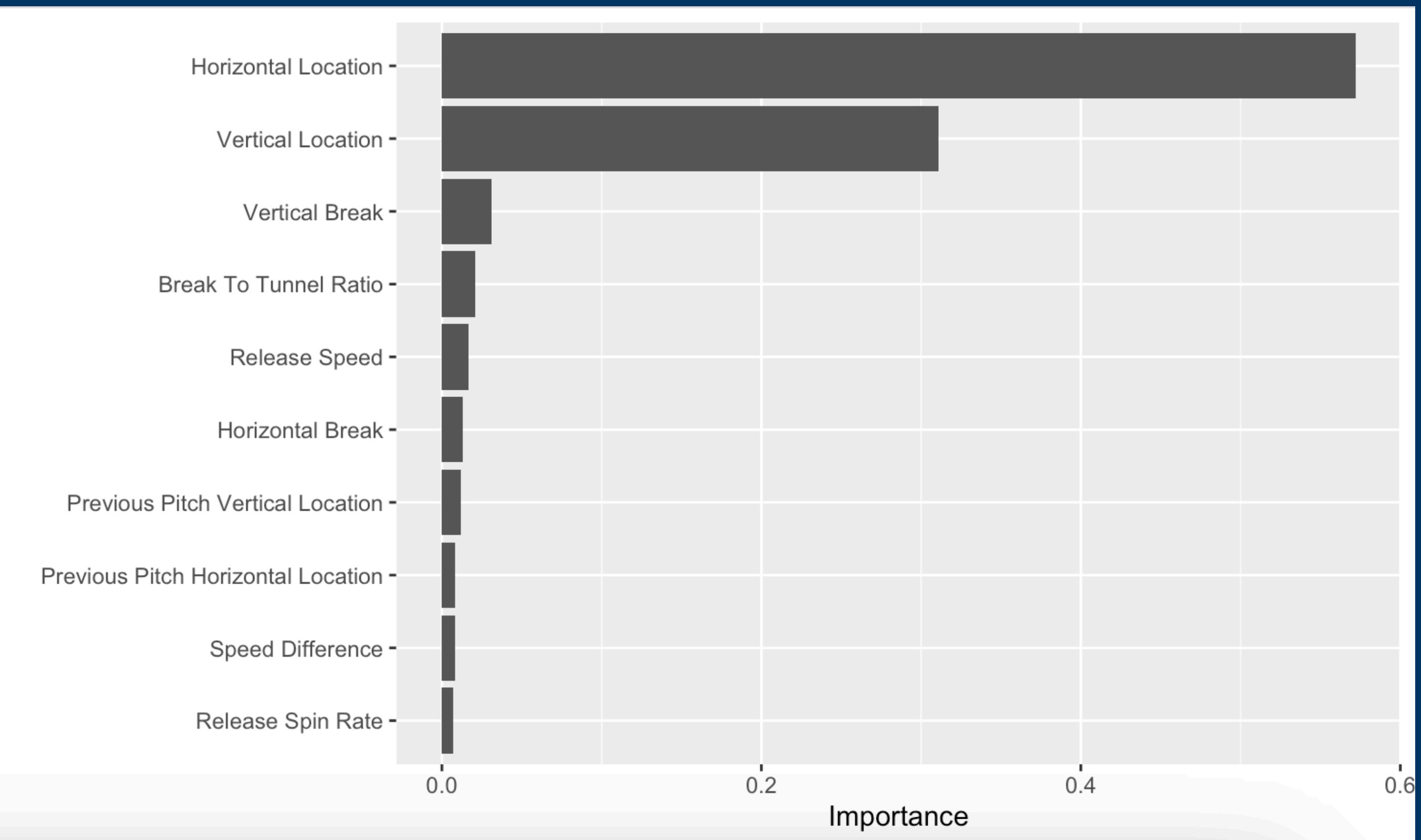


# Four-Seam -> Slider | RHP -> LHH | Chase

**Training Sample: n = 17778 pitches**

**Testing Sample: n = 7620 pitches**

**Testing Accuracy: 70.26%**

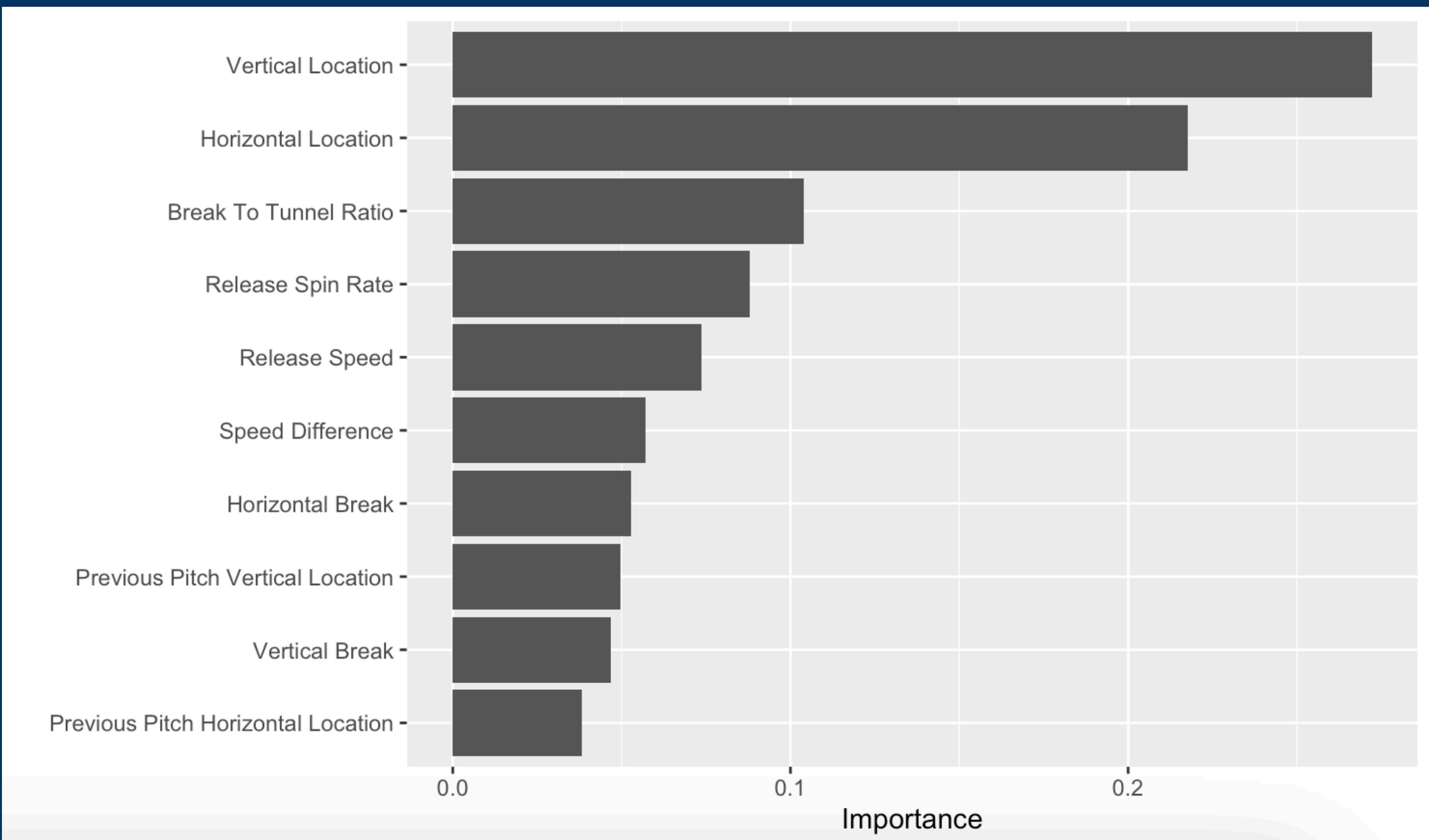


# Four-Seam -> Sweeper | RHP -> LHH | Whiff

**Training Sample: n = 696 pitches**

**Testing Sample: n = 300 pitches**

**Testing Accuracy: 65.33%**

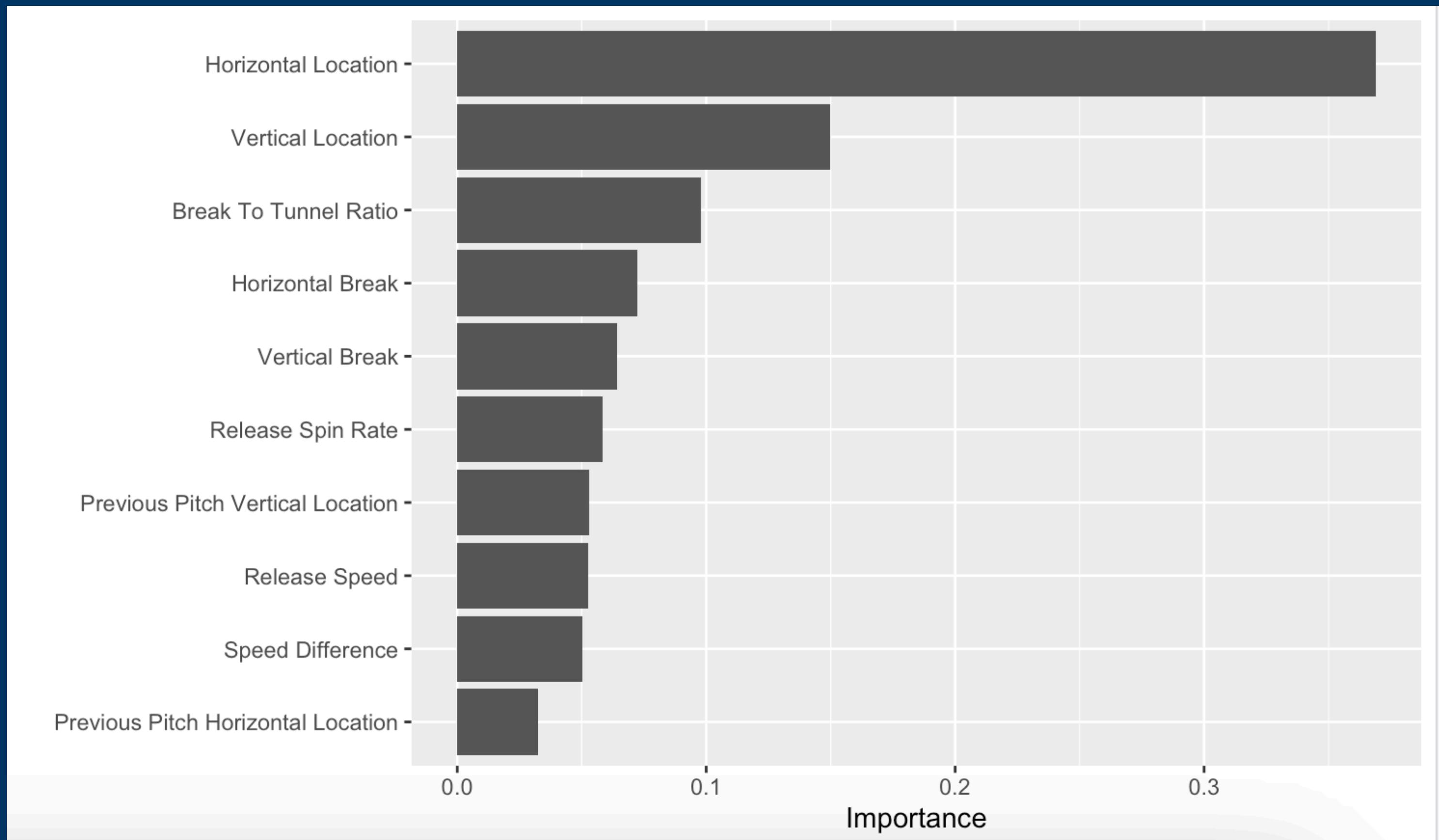


# Four-Seam -> Sweeper | RHP -> LHH | Chase

**Training Sample: n = 968 pitches**

**Testing Sample: n = 416 pitches**

**Testing Accuracy: 70.43%**

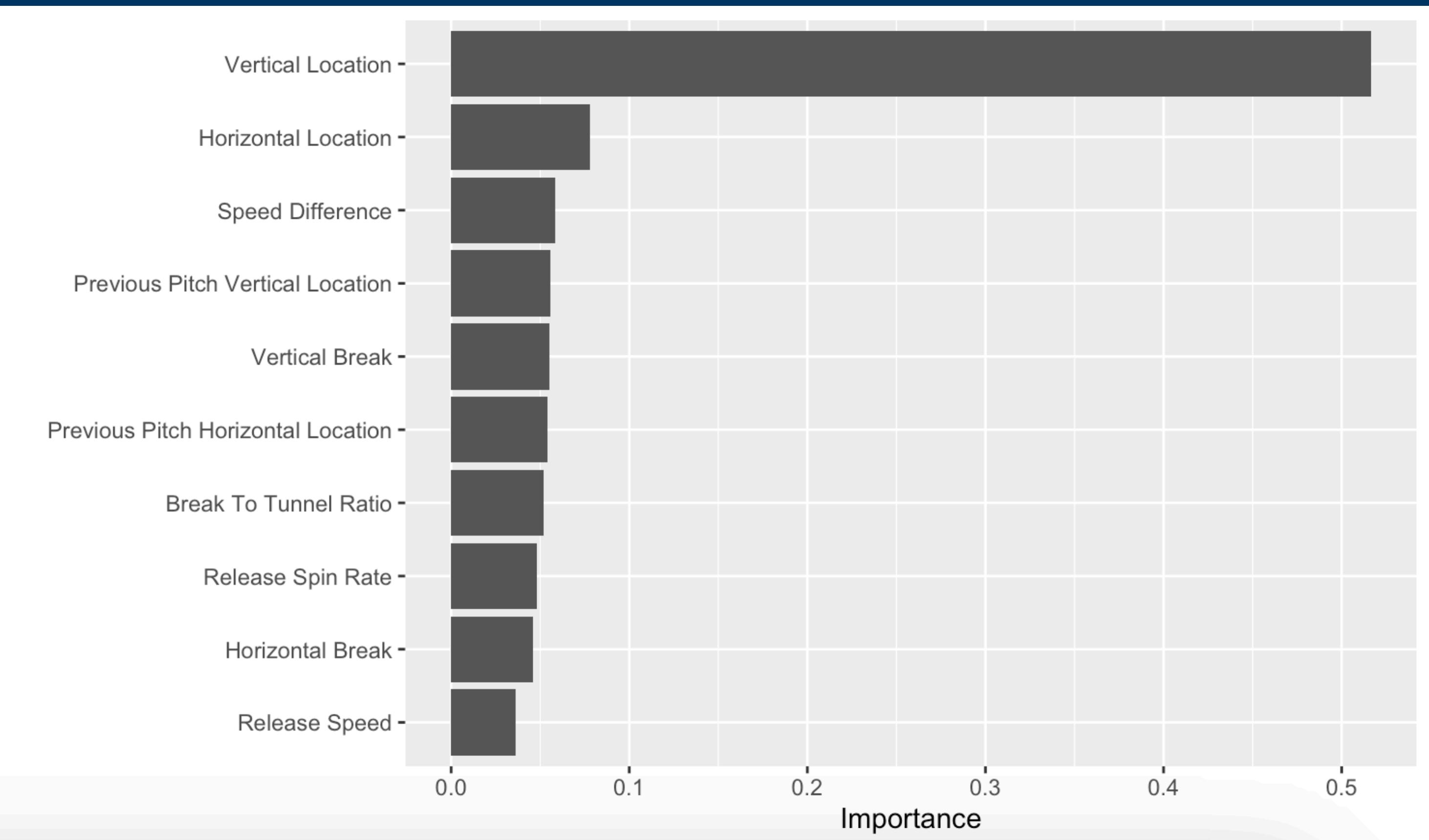


# Sinker -> Changeup | RHP -> LHH | Whiff

**Training Sample: n = 6556 pitches**

**Testing Sample: n = 2810 pitches**

**Testing Accuracy: 63.99%**

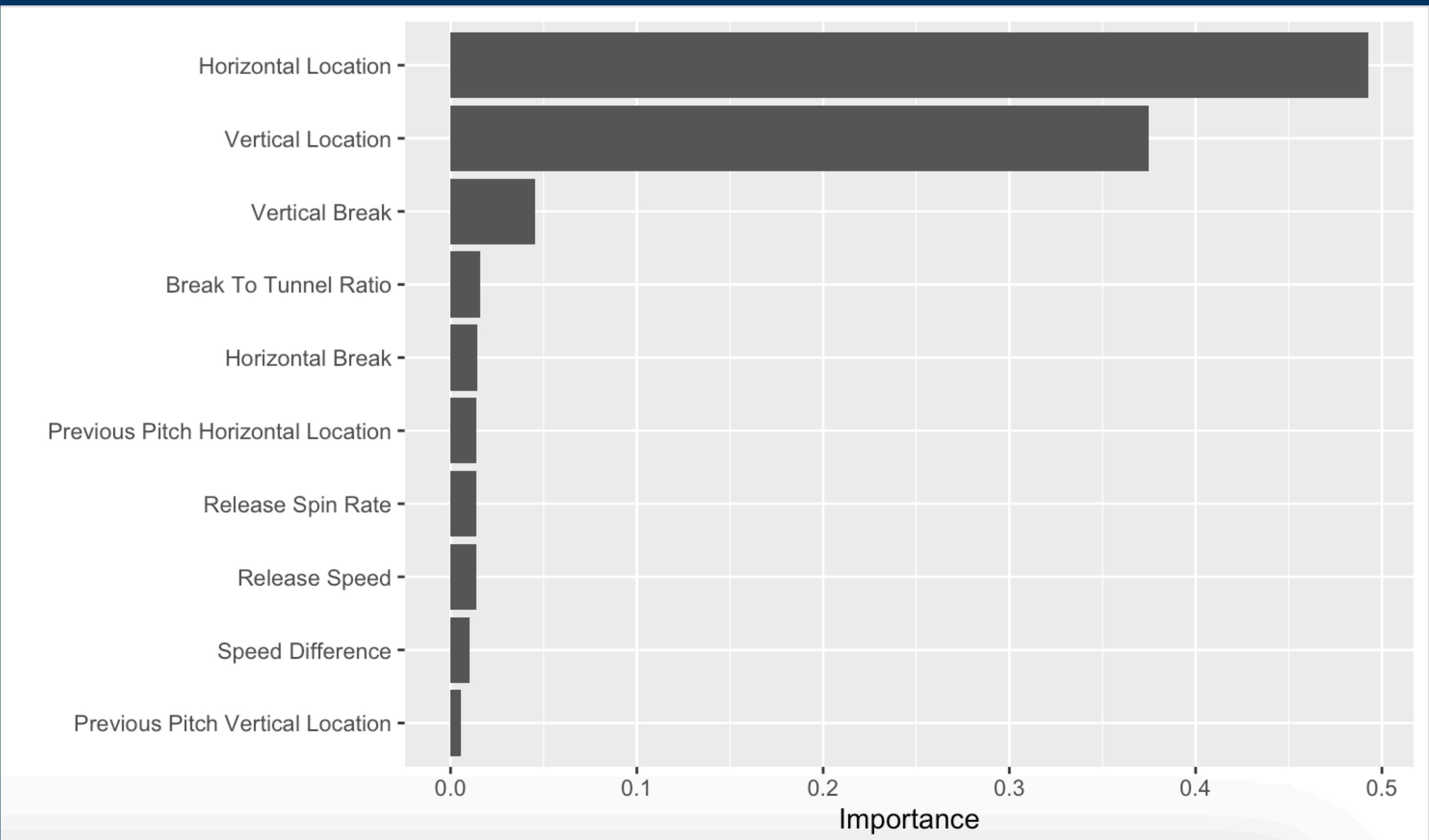


# Sinker -> Changeup | RHP -> LHH | Chase

**Training Sample: n = 11752 pitches**

**Testing Sample: n = 5038 pitches**

**Testing Accuracy: 72.71%**

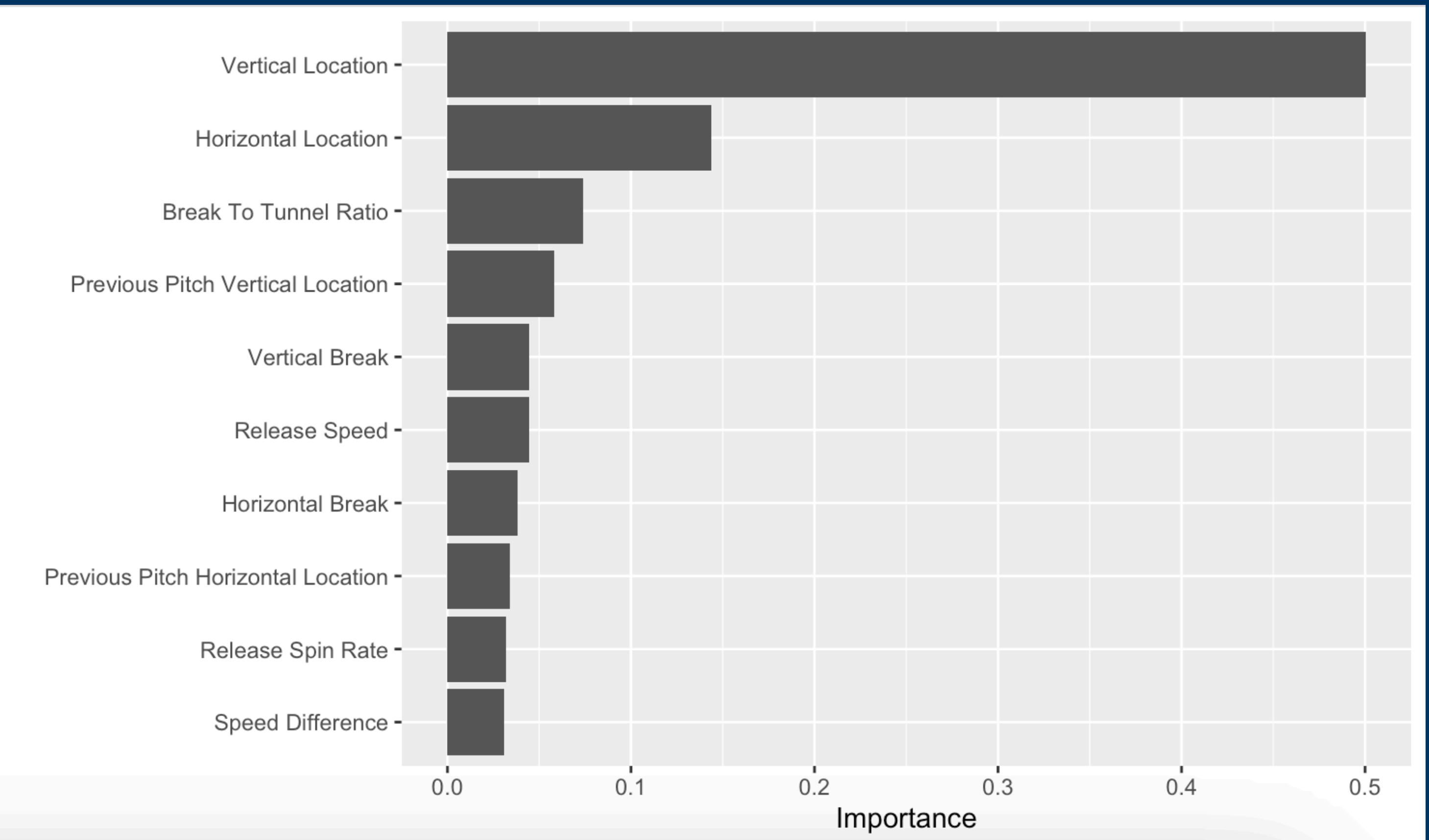


# Sinker -> Curveball | RHP -> LHH | Whiff

**Training Sample: n = 2880 pitches**

**Testing Sample: n = 1236 pitches**

**Testing Accuracy: 72.17%**

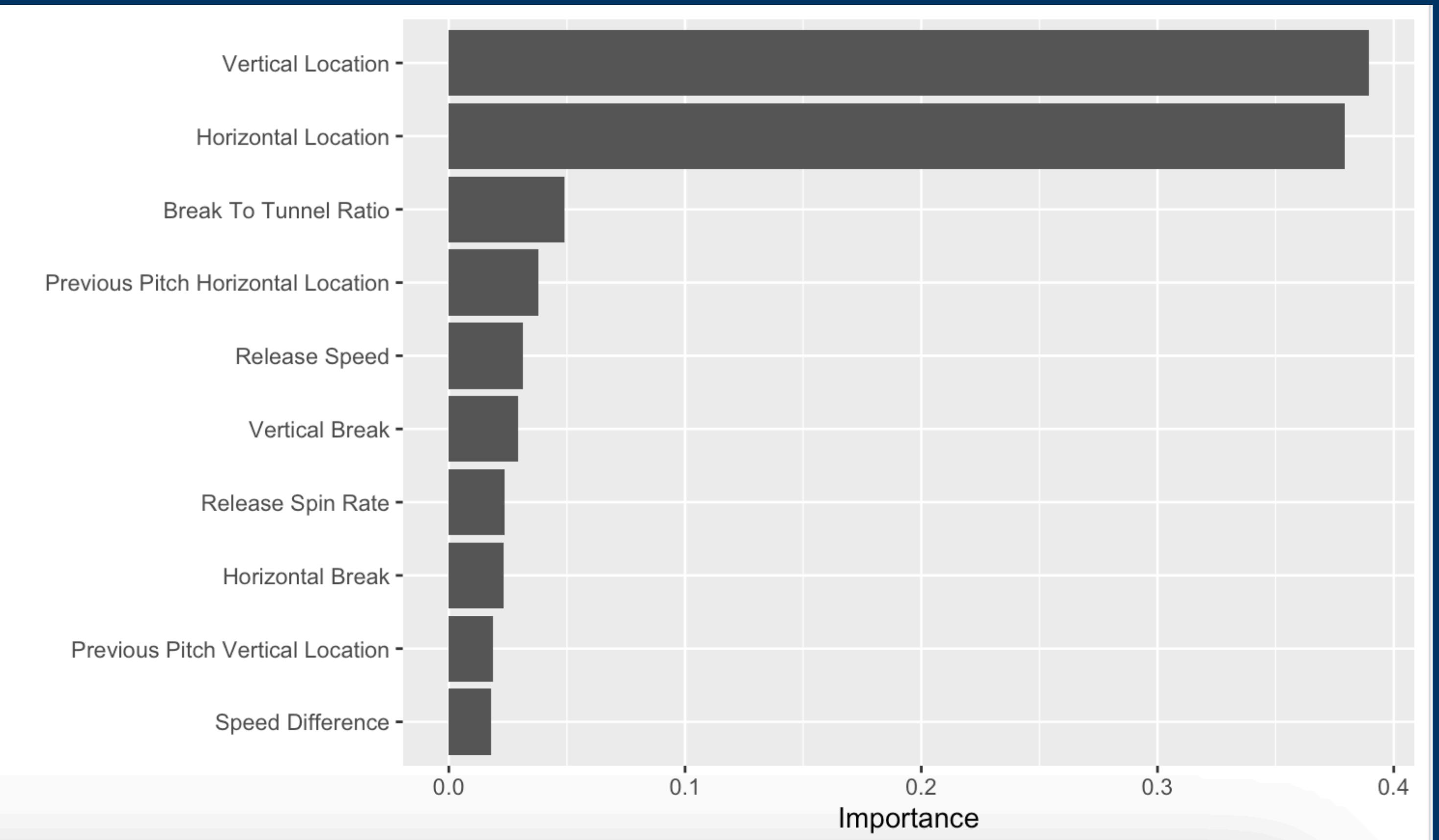


# Sinker -> Curveball | RHP -> LHH | Chase

**Training Sample: n = 4386 pitches**

**Testing Sample: n = 1882 pitches**

**Testing Accuracy: 73.43%**

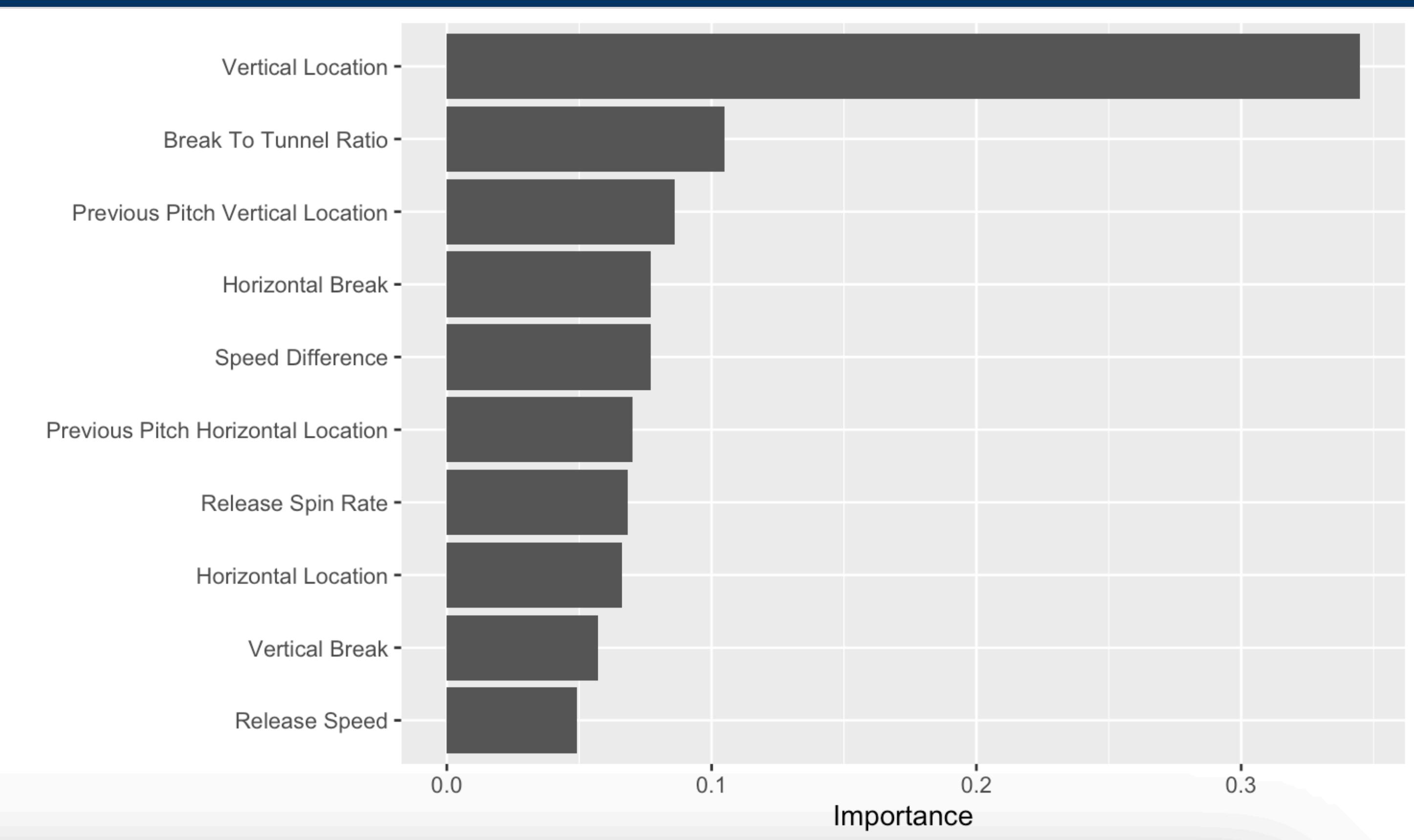


# Sinker -> Splitter | RHP -> LHH | Whiff

**Training Sample: n = 1190 pitches**

**Testing Sample: n = 512 pitches**

**Testing Accuracy: 65.82%**

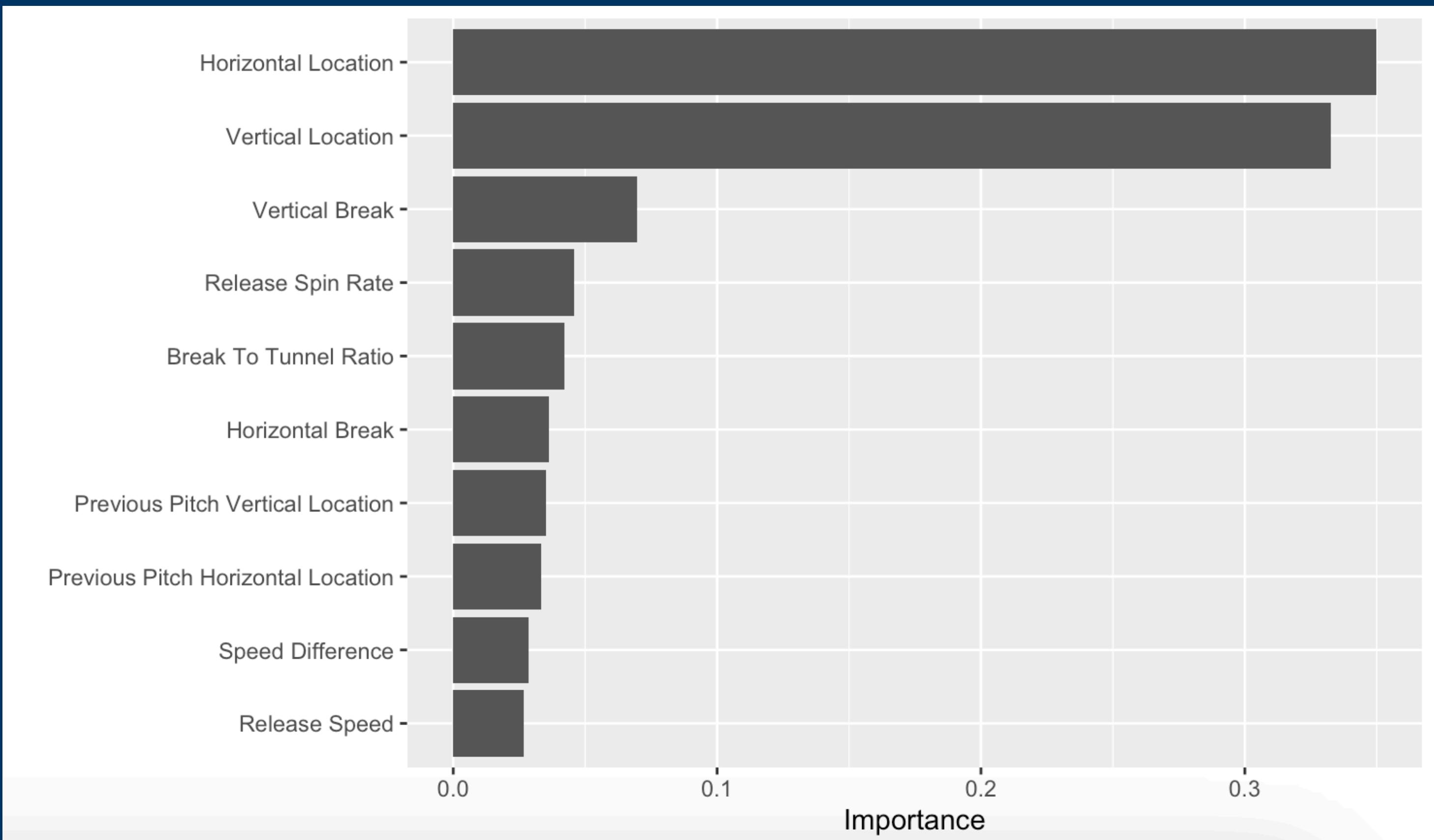


# Sinker -> Splitter | RHP -> LHH | Chase

**Training Sample: n = 2048 pitches**

**Testing Sample: n = 878 pitches**

**Testing Accuracy: 72.10%**

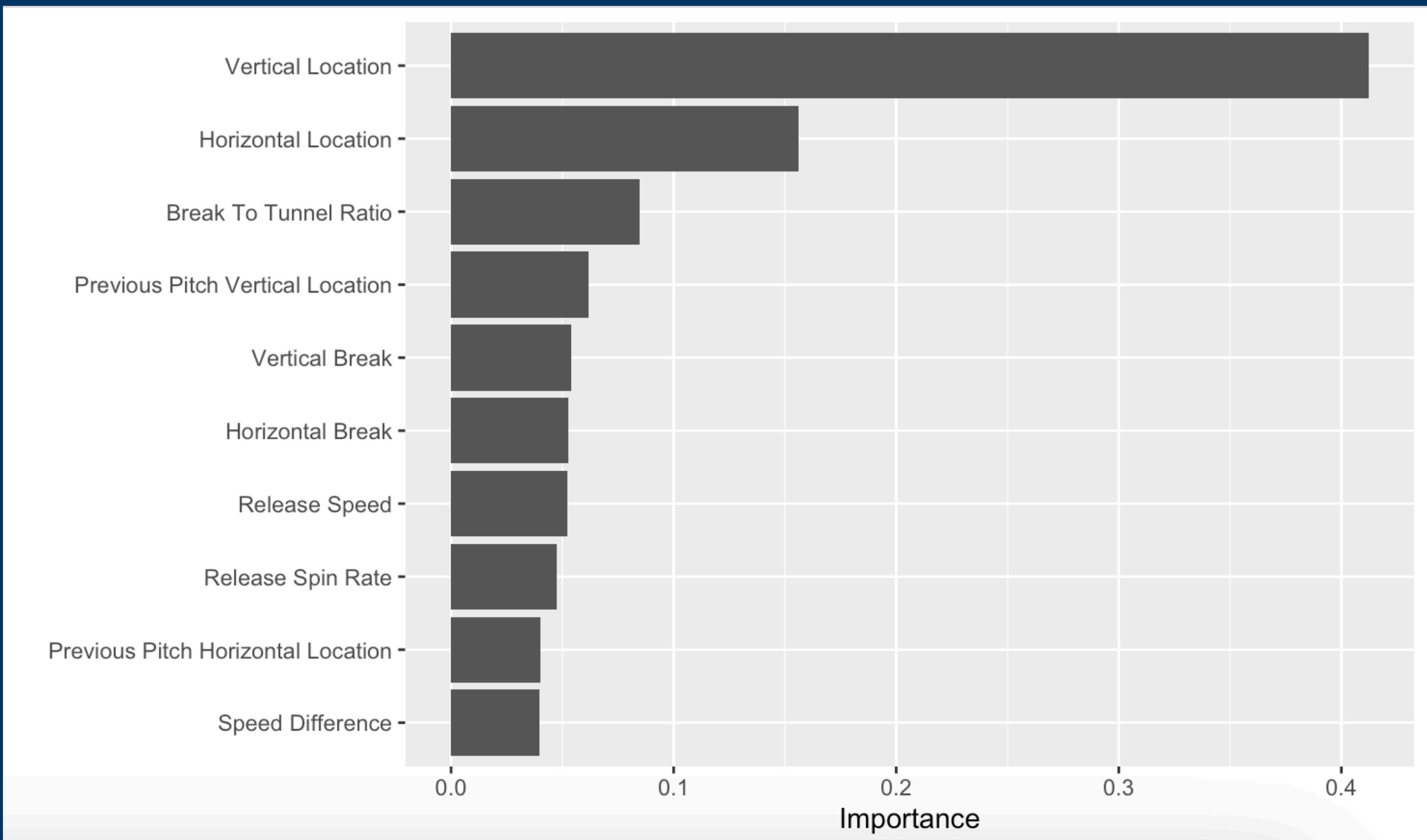


# Sinker -> Knuckle Curve | RHP -> LHH | Whiff

**Training Sample: n = 974 pitches**

**Testing Sample: n = 418 pitches**

**Testing Accuracy: 71.29%**

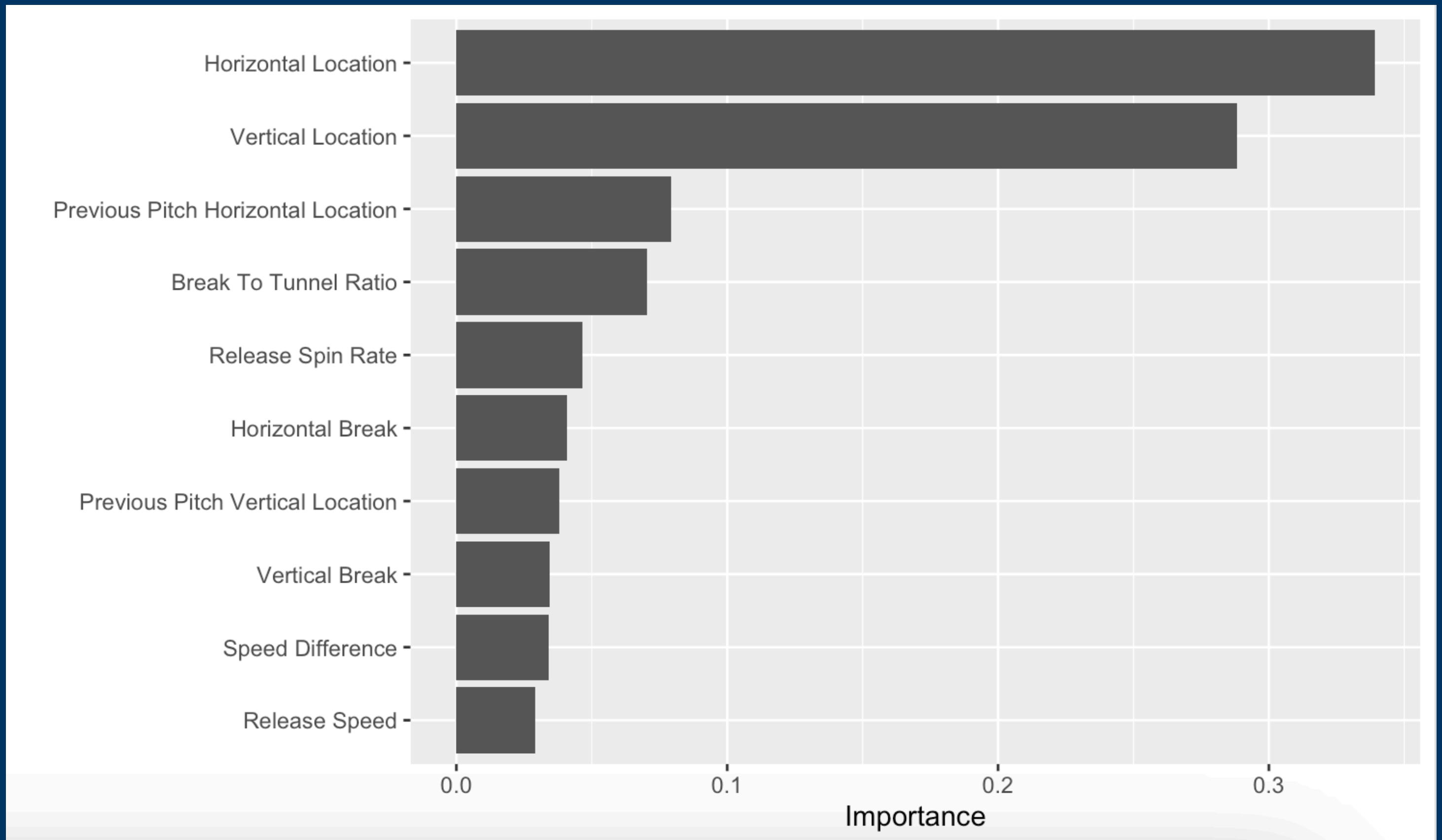


# Sinker -> Knuckle Curve | RHP -> LHH | Chase

**Training Sample: n = 1418 pitches**

**Testing Sample: n = 610 pitches**

**Testing Accuracy: 71.80%**

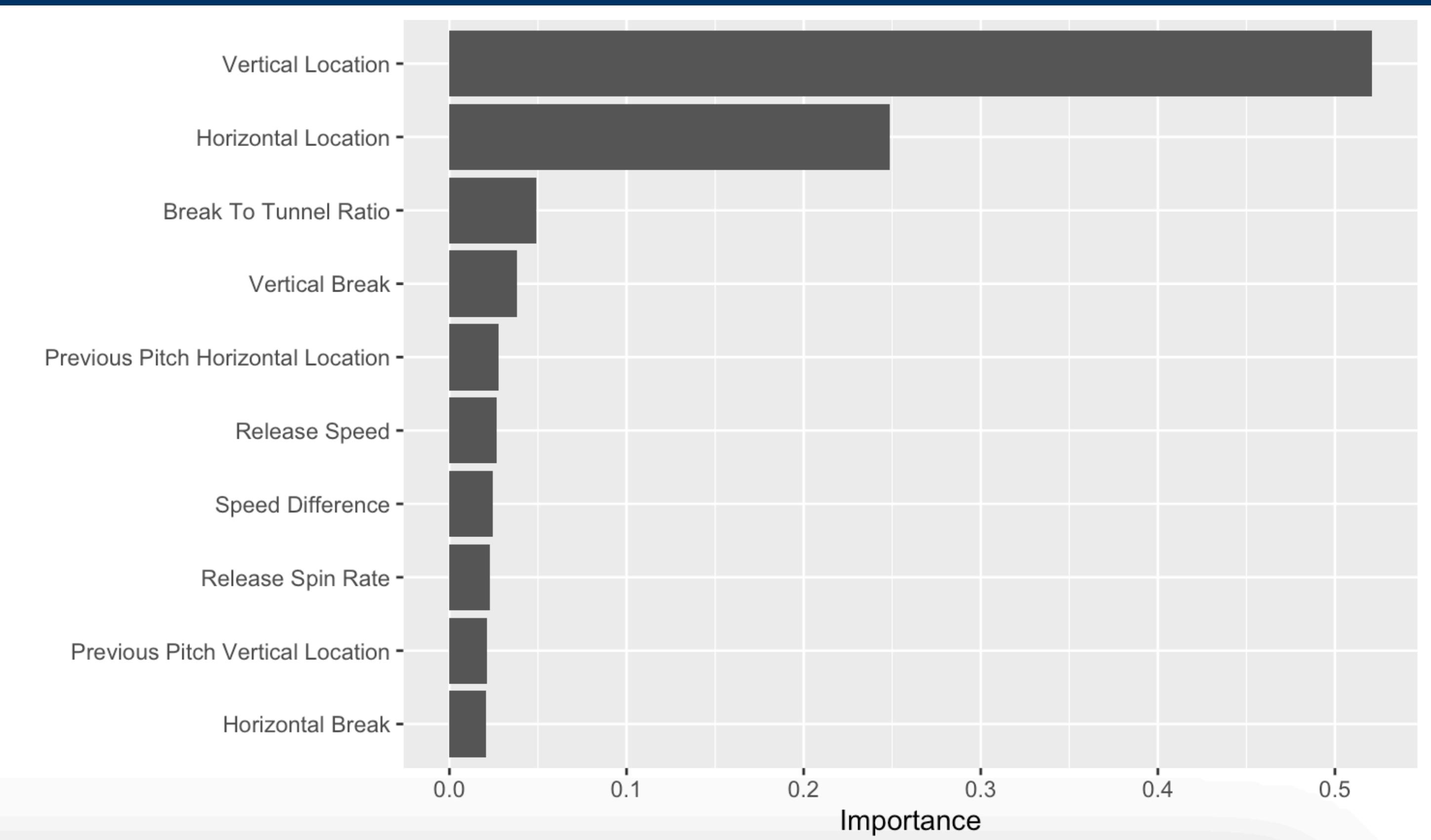


# Sinker -> Slider | RHP -> LHH | Whiff

**Training Sample: n = 5202 pitches**

**Testing Sample: n = 2232 pitches**

**Testing Accuracy: 69.67%**

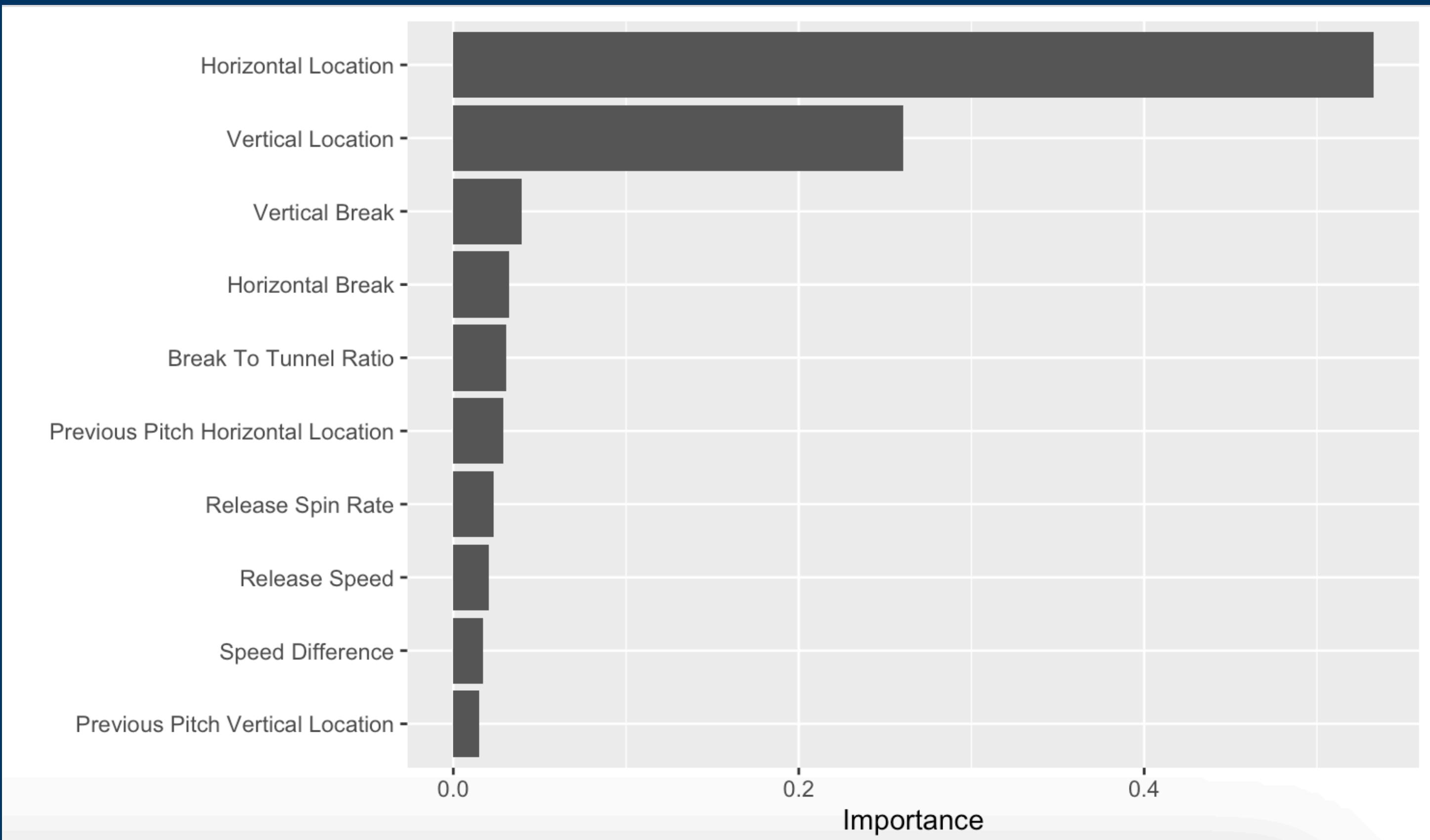


# Sinker -> Slider | RHP -> LHH | Chase

**Training Sample: n = 6984 pitches**

**Testing Sample: n = 2994 pitches**

**Testing Accuracy: 71.41%**

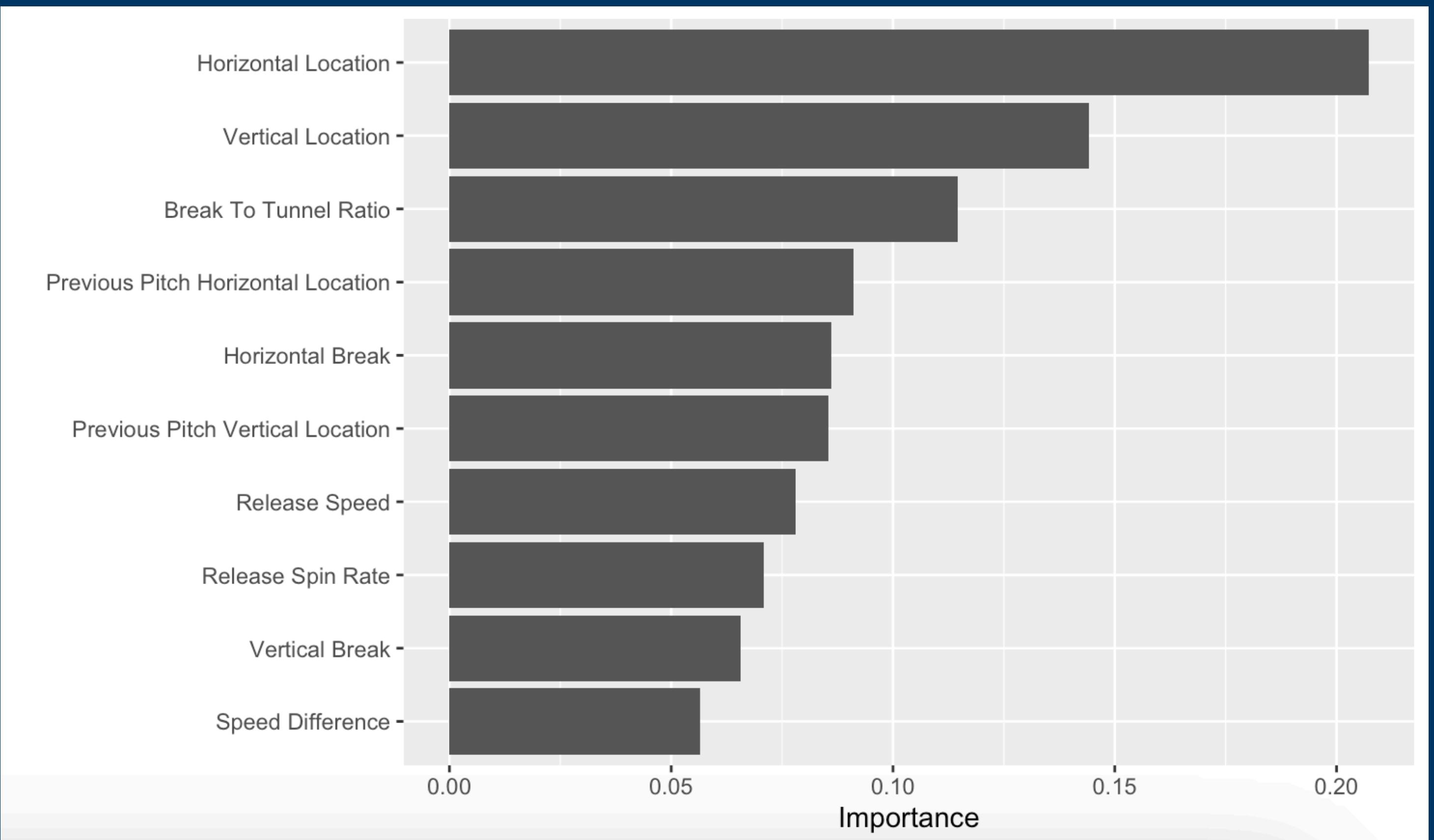


# Sinker -> Sweeper | RHP -> LHH | Whiff

**Training Sample: n = 284 pitches**

**Testing Sample: n = 124 pitches**

**Testing Accuracy: 69.35%**

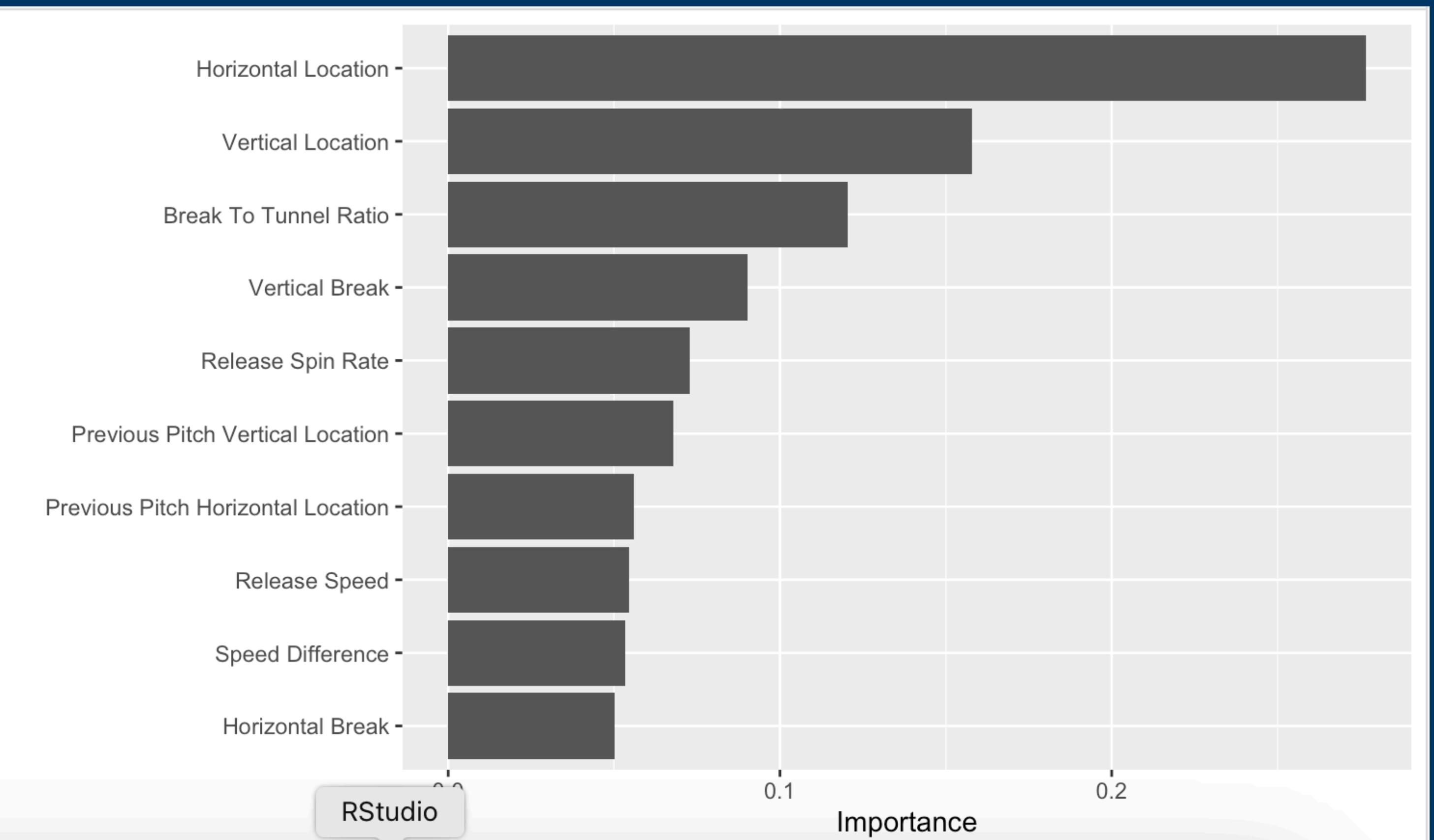


# Sinker -> Sweeper | RHP -> LHH | Chase

**Training Sample: n = 364 pitches**

**Testing Sample: n = 158 pitches**

**Testing Accuracy: 63.29%**



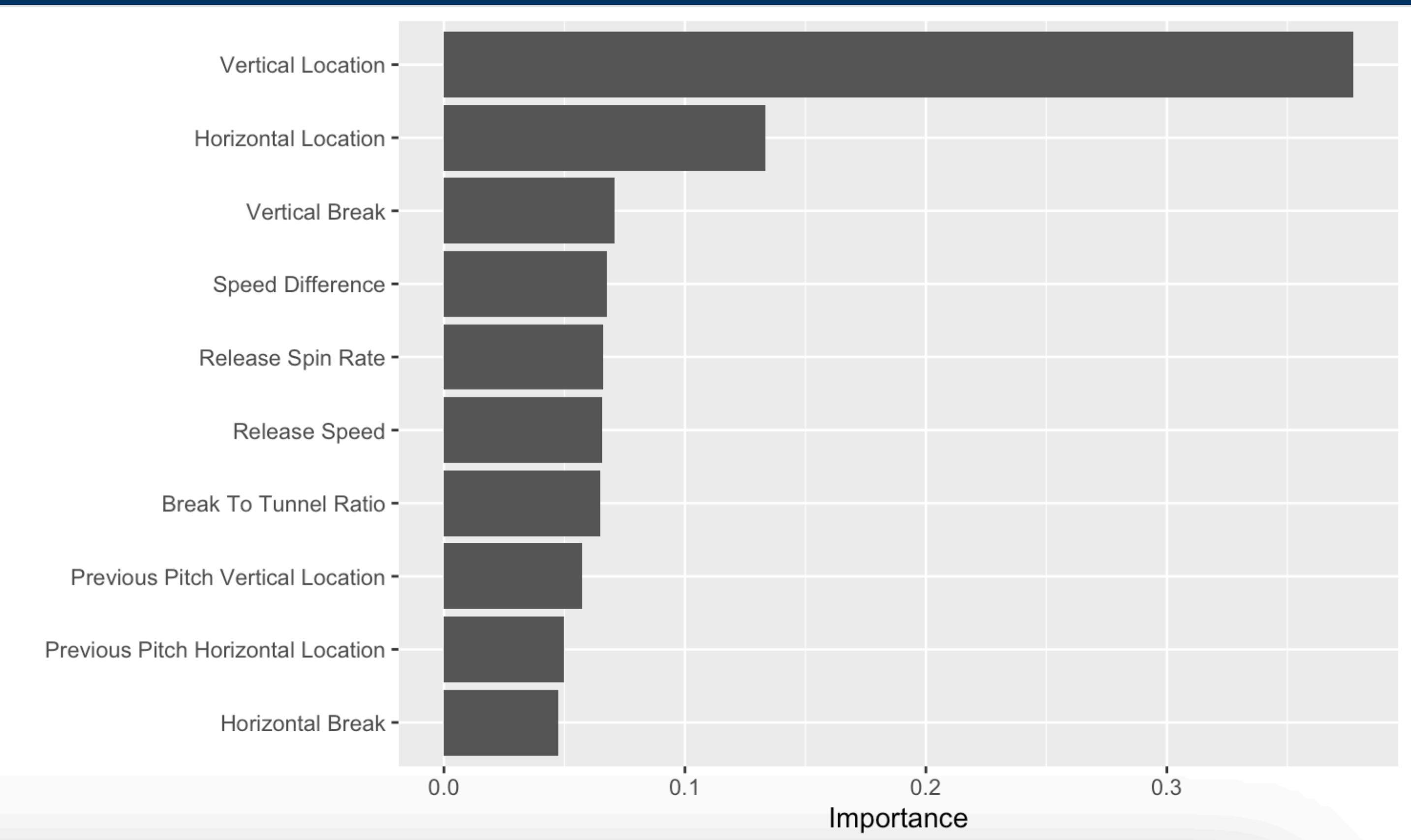
# Left Handed Pitchers vs Right Handed Hitters

# Cutter -> Changeup | LHP -> RHH | Whiff

**Training Sample: n = 2390 pitches**

**Testing Sample: n = 1026 pitches**

**Testing Accuracy: 64.04%**

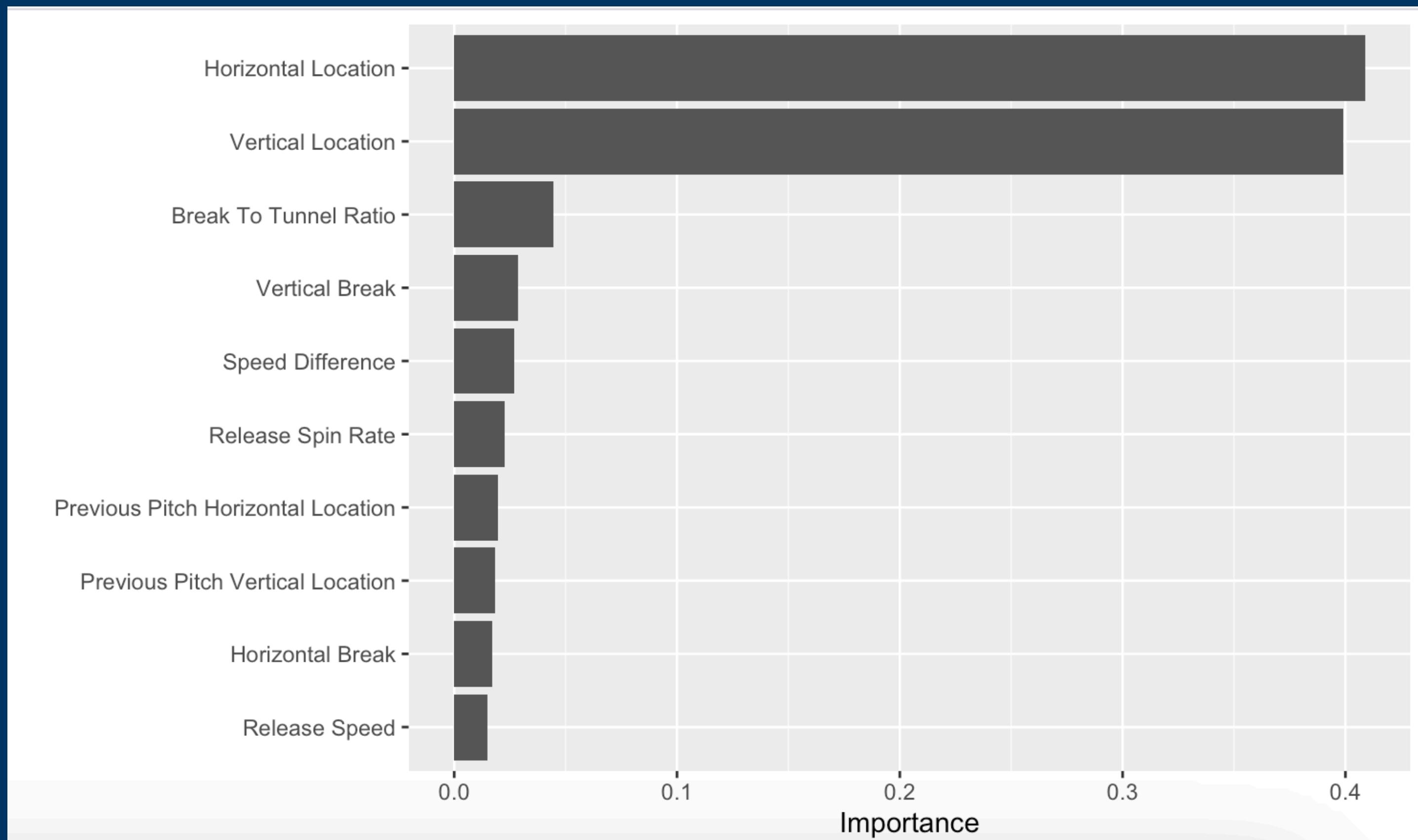


# Cutter -> Changeup | LHP -> RHH | Chase

**Training Sample: n = 4502 pitches**

**Testing Sample: n = 1930 pitches**

**Testing Accuracy: 71.50%**

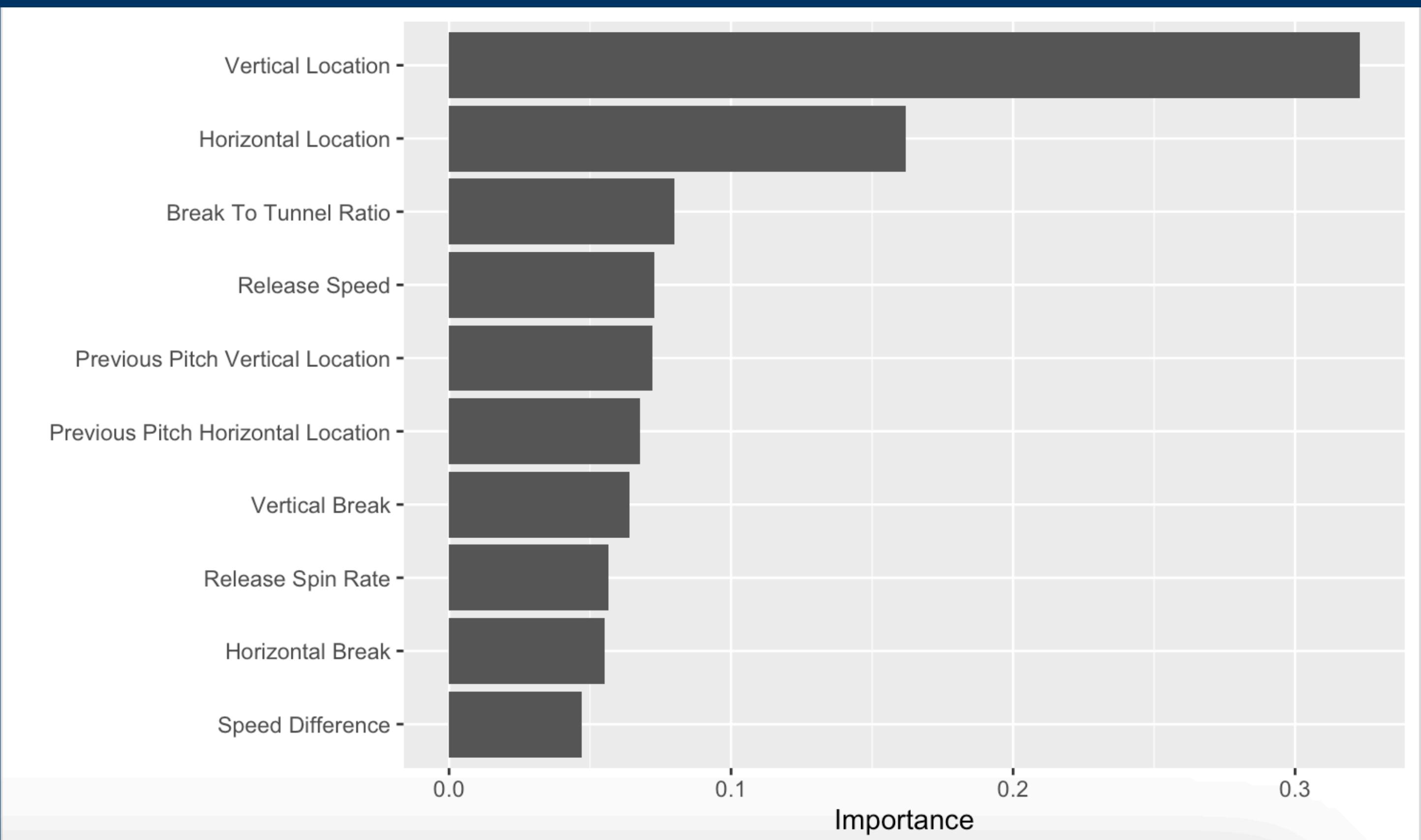


# Cutter -> Curveball | LHP -> RHH | Whiff

**Training Sample: n = 922 pitches**

**Testing Sample: n = 396 pitches**

**Testing Accuracy: 70.45%**

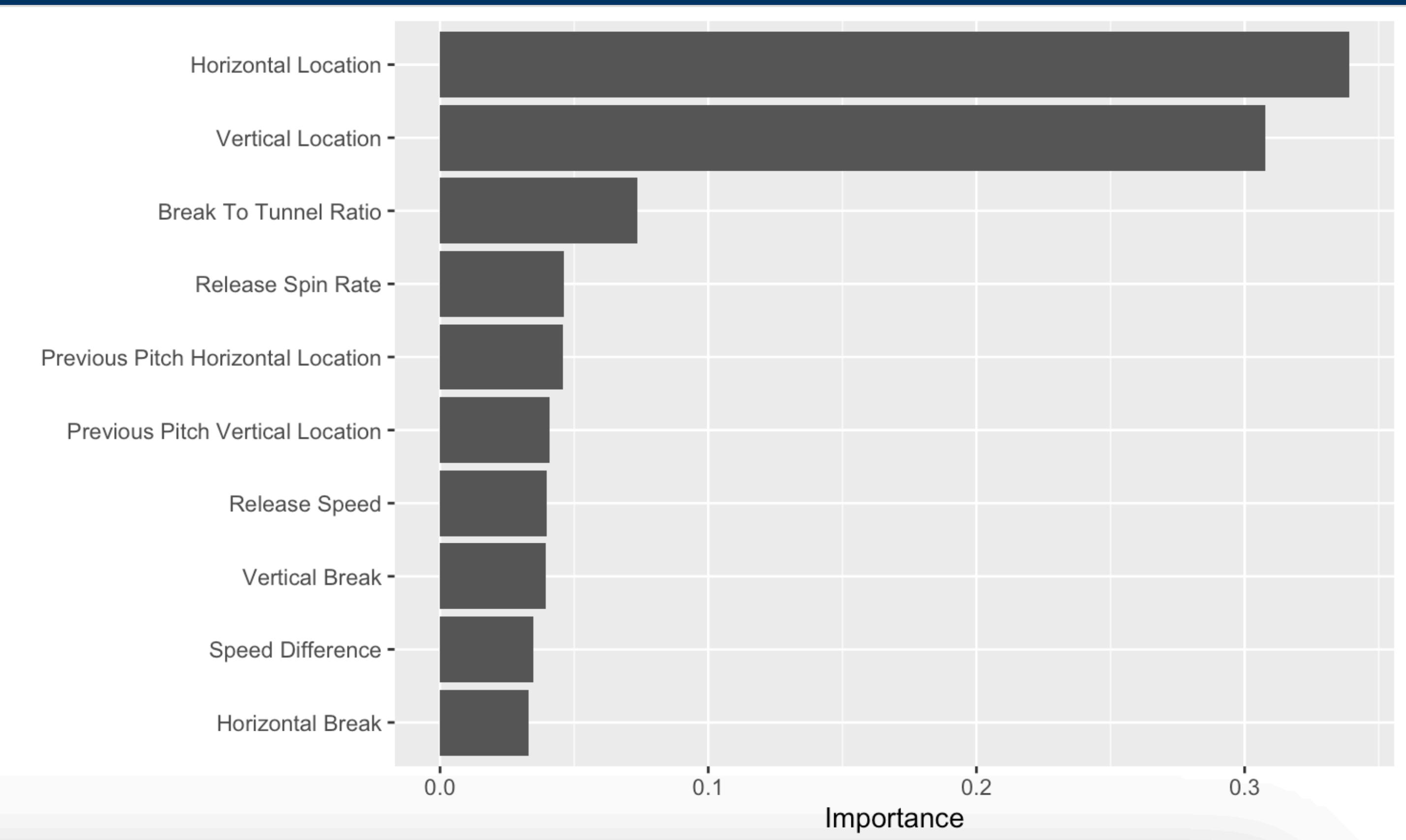


# Cutter -> Curveball | LHP -> RHH | Chase

**Training Sample: n = 1476 pitches**

**Testing Sample: n = 634 pitches**

**Testing Accuracy: 72.08%**

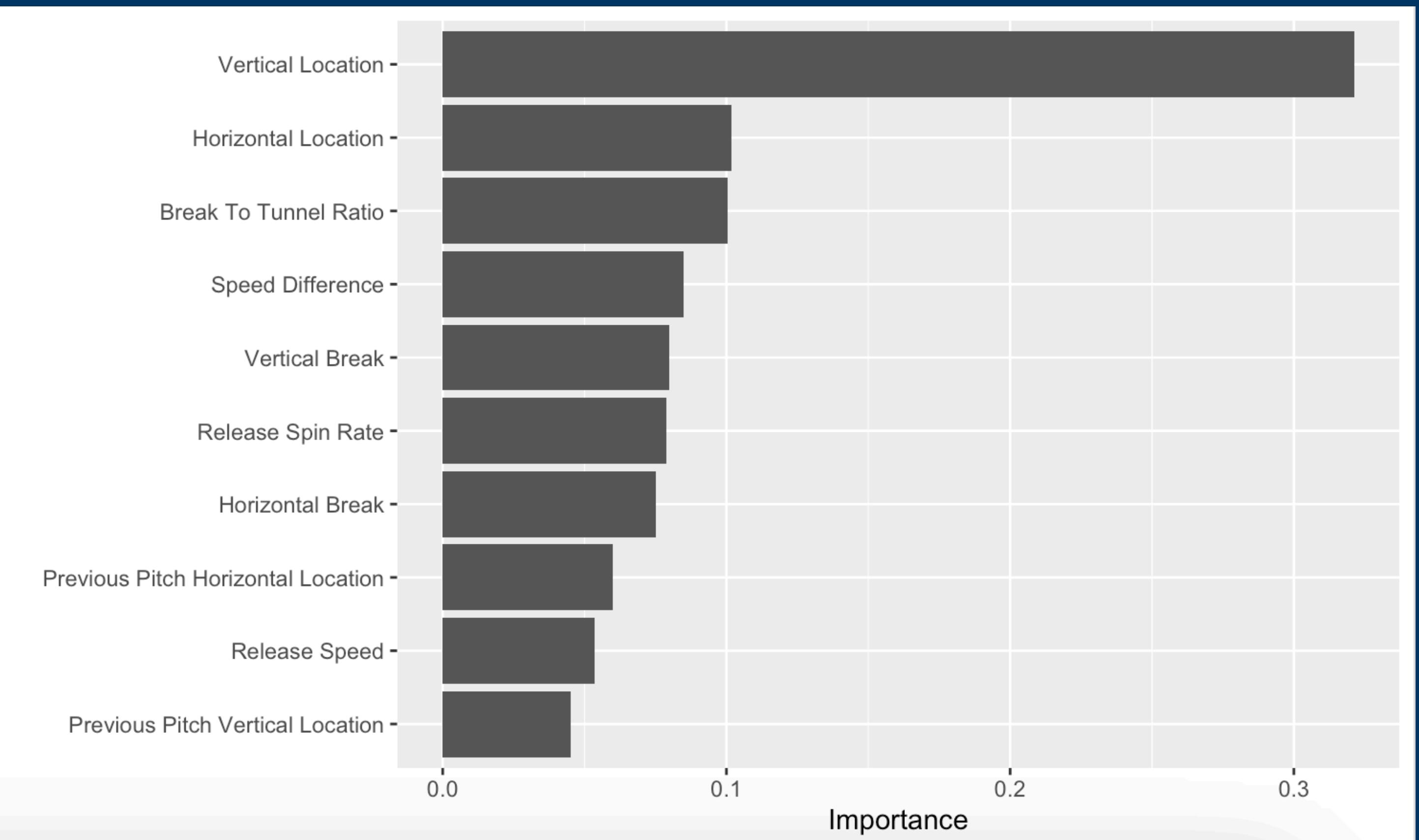


# Cutter -> Slider | LHP -> RHH | Whiff

**Training Sample: n = 320 pitches**

**Testing Sample: n = 138 pitches**

**Testing Accuracy: 72.46%**

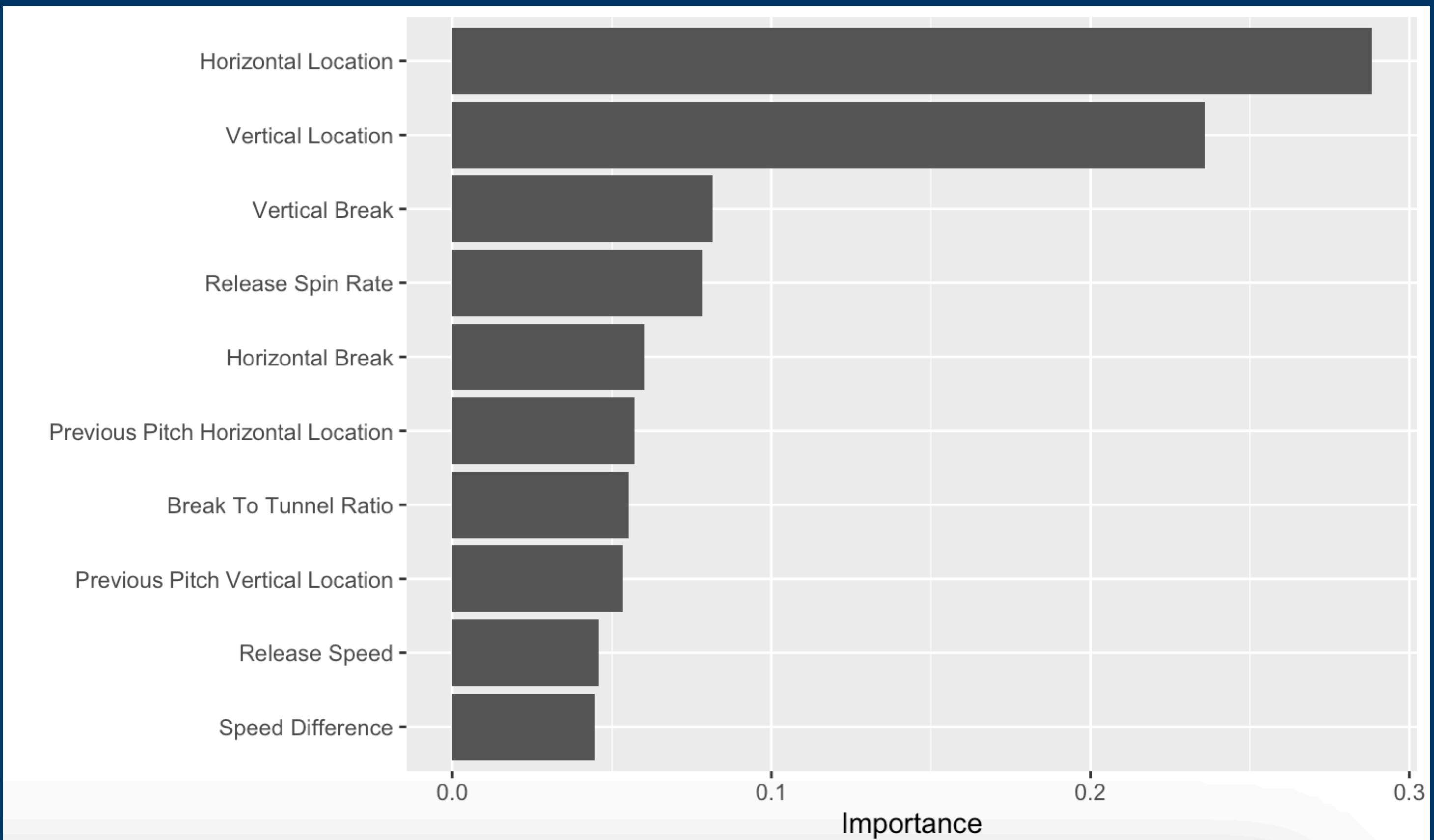


# Cutter -> Slider | LHP -> RHH | Chase

**Training Sample: n = 518 pitches**

**Testing Sample: n = 224 pitches**

**Testing Accuracy: 67.41%**

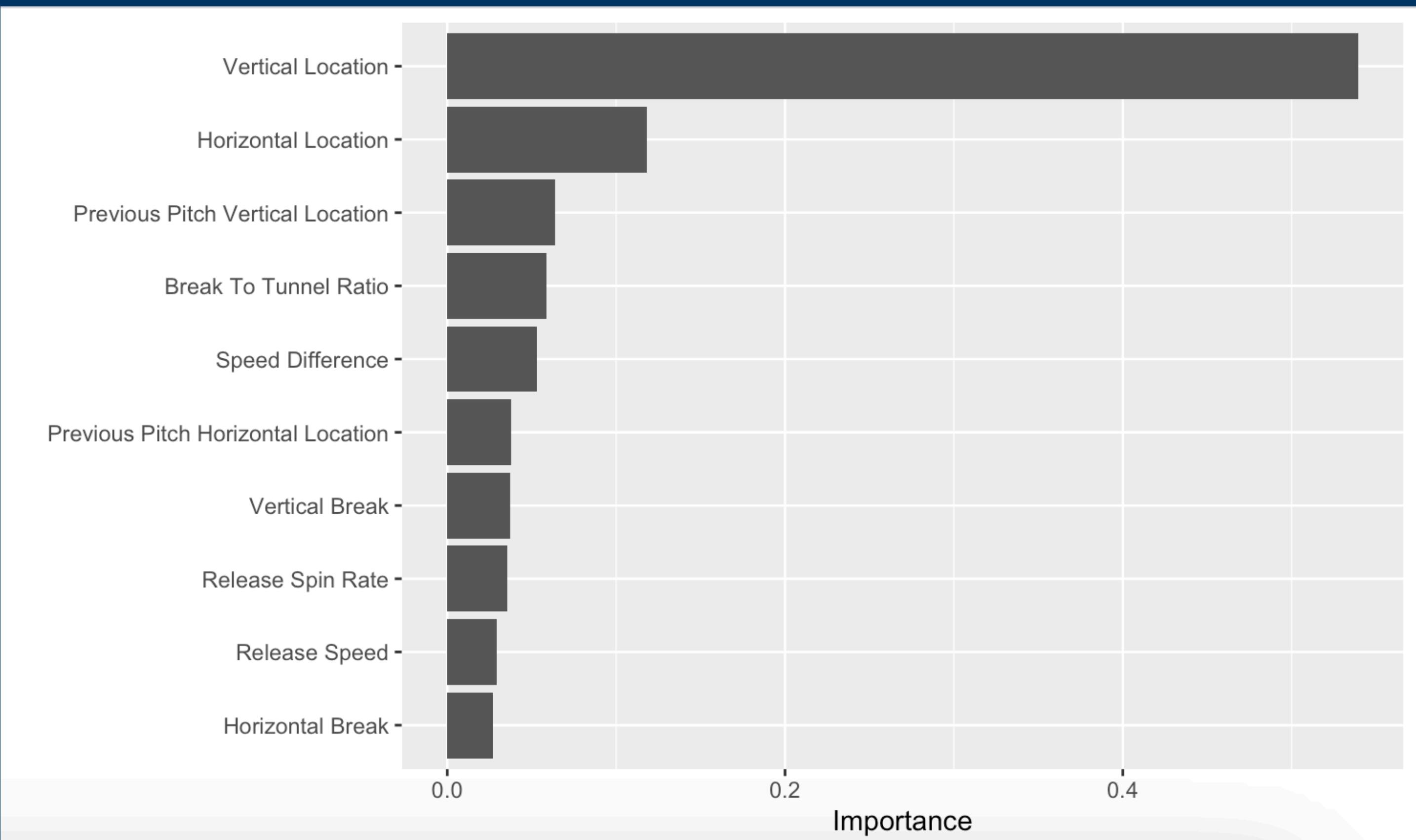


# Four-Seam -> Changeup | LHP -> RHH | Whiff

**Training Sample: n = 9542 pitches**

**Testing Sample: n = 4090 pitches**

**Testing Accuracy: 63.55%**

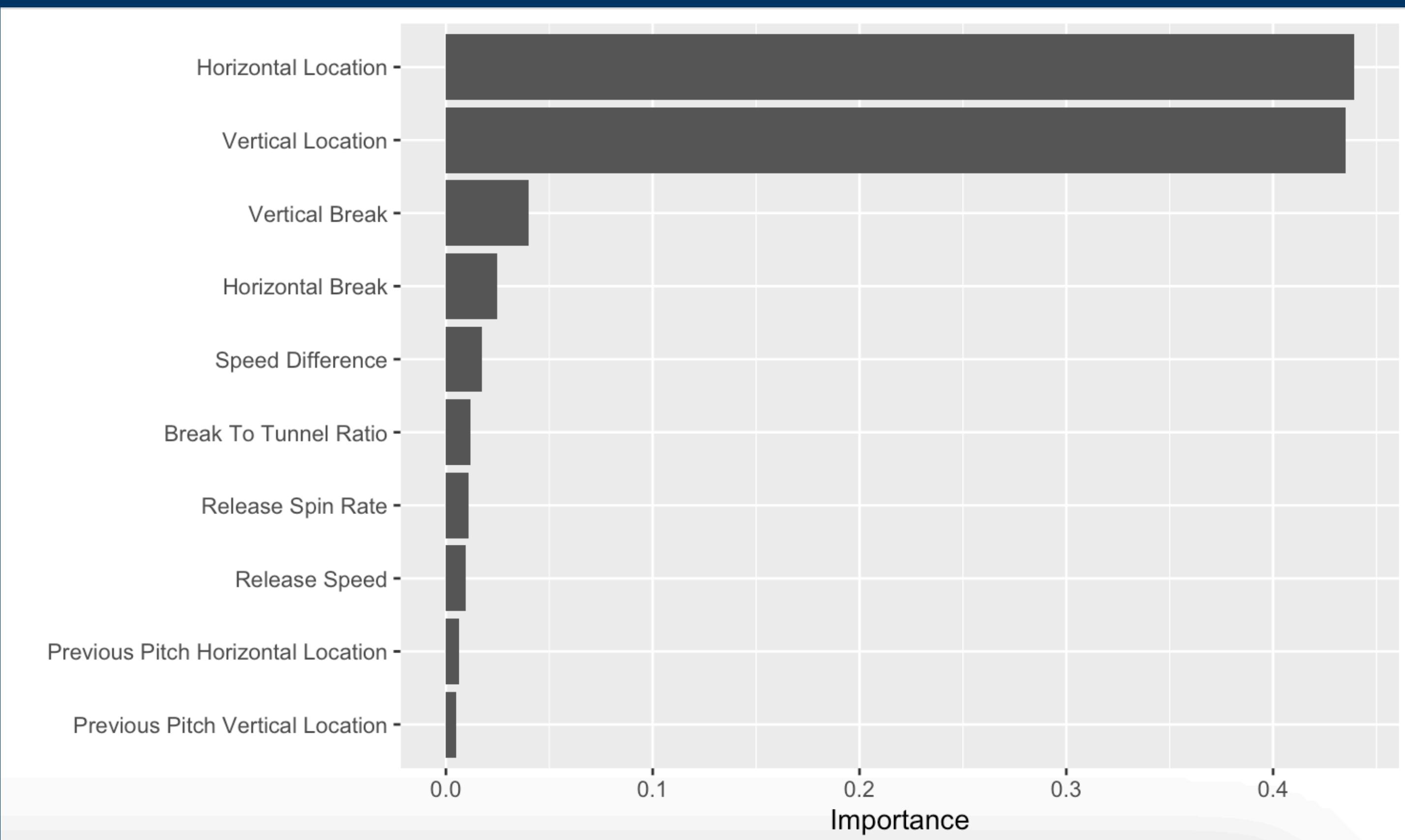


# Four-Seam -> Changeup | LHP -> RHH | Chase

**Training Sample: n = 15356 pitches**

**Testing Sample: n = 6584 pitches**

**Testing Accuracy: 72.93%**

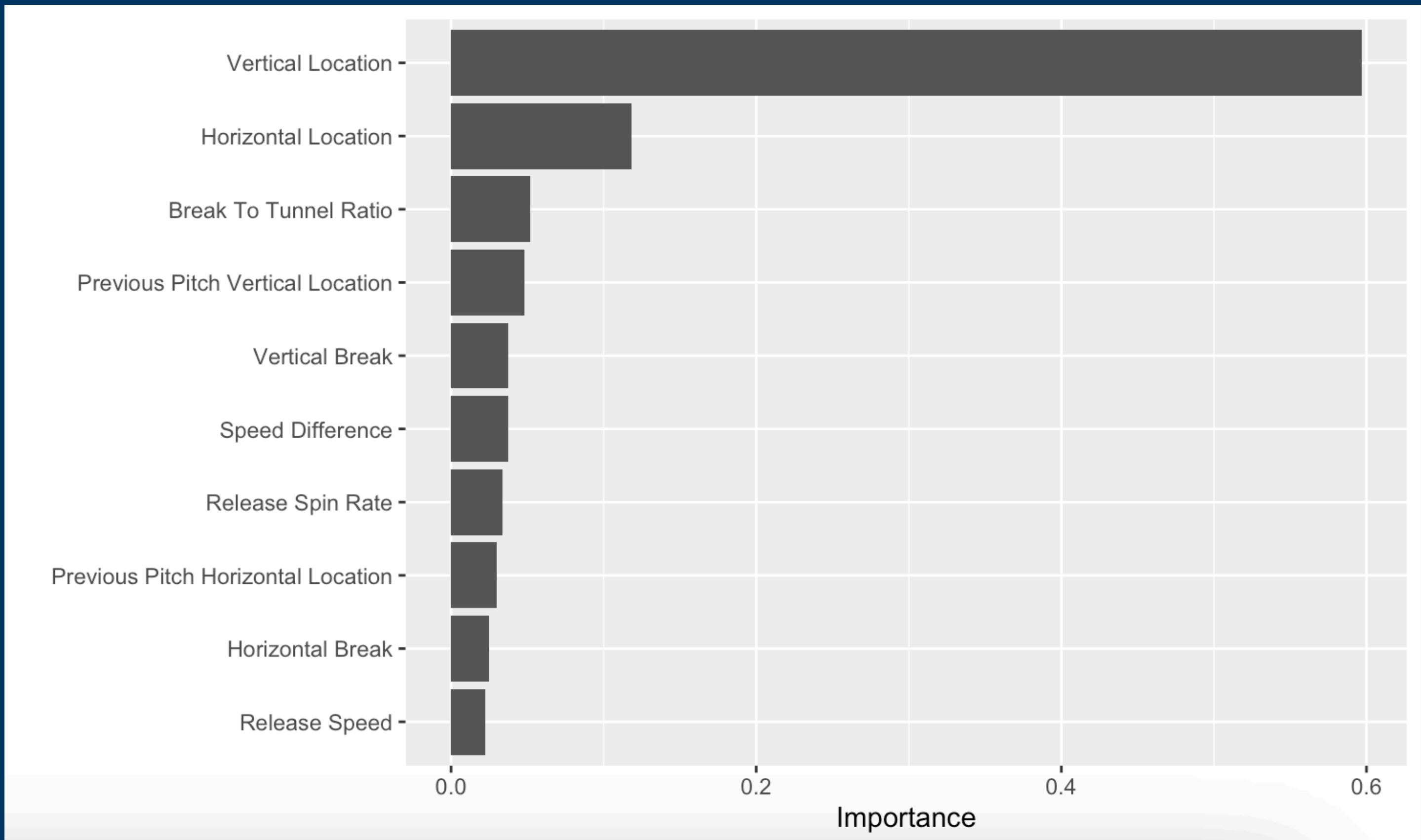


# Four-Seam -> Curveball | LHP -> RHH | Whiff

**Training Sample: n = 4698 pitches**

**Testing Sample: n = 2016 pitches**

**Testing Accuracy: 72.27%**

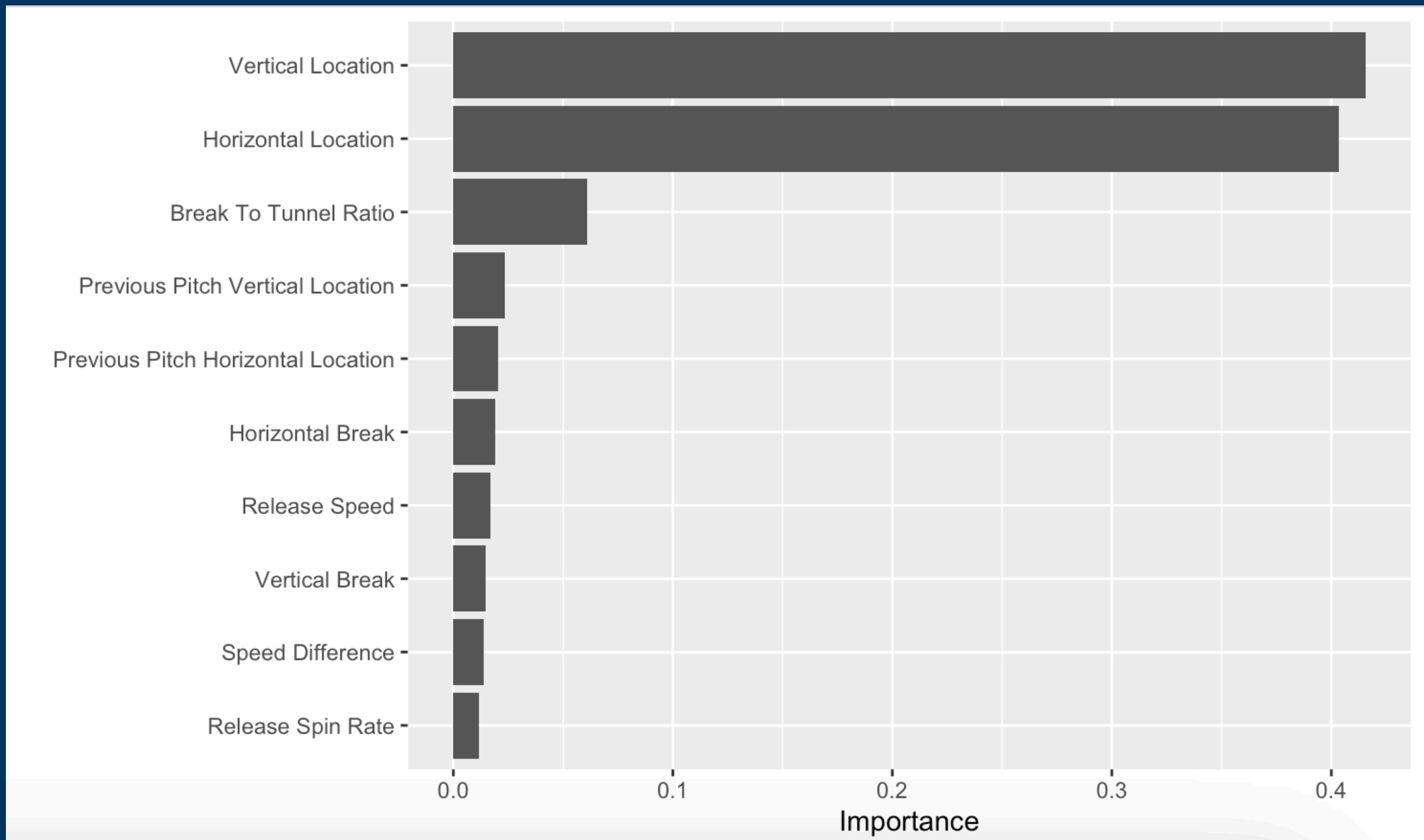


# Four-Seam -> Curveball | LHP -> RHH | Chase

**Training Sample: n = 7360 pitches**

**Testing Sample: n = 3156 pitches**

**Testing Accuracy: 71.83%**

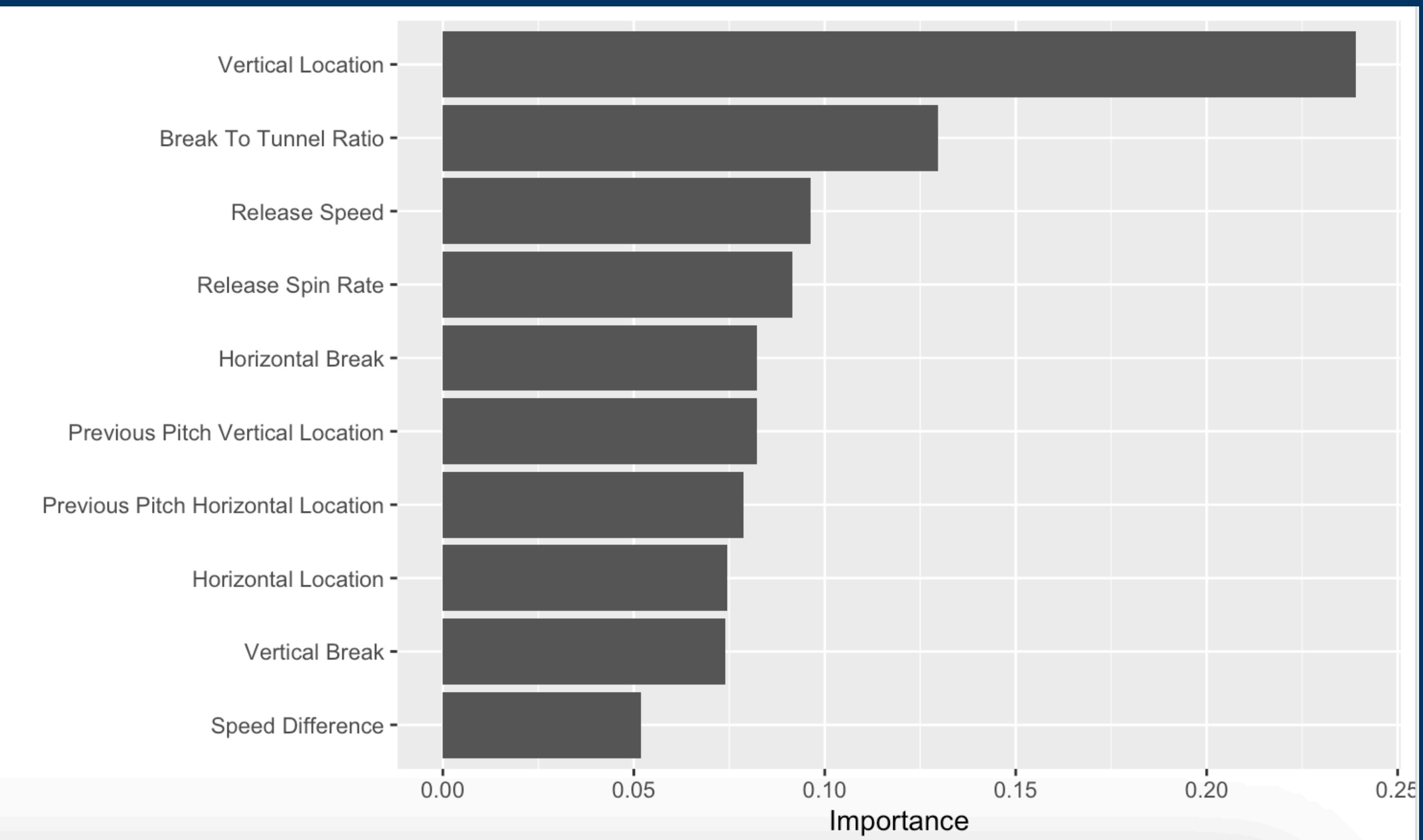


# Four-Seam -> Splitter | LHP -> RHH | Whiff

**Training Sample: n = 430 pitches**

**Testing Sample: n = 186 pitches**

**Testing Accuracy: 68.82%**

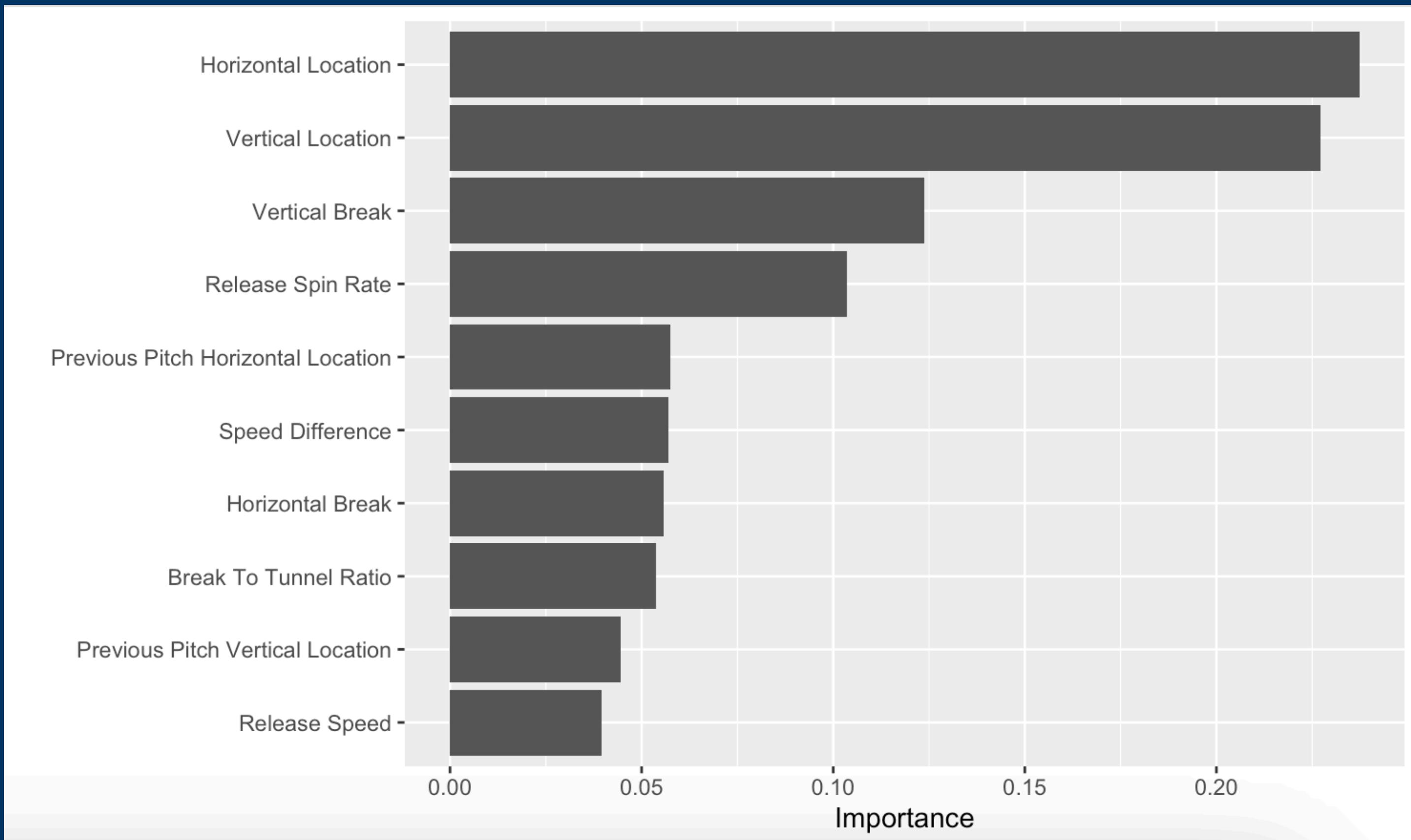


# Four-Seam -> Splitter | LHP -> RHH | Chase

**Training Sample: n = 612 pitches**

**Testing Sample: n = 264 pitches**

**Testing Accuracy: 77.27%**

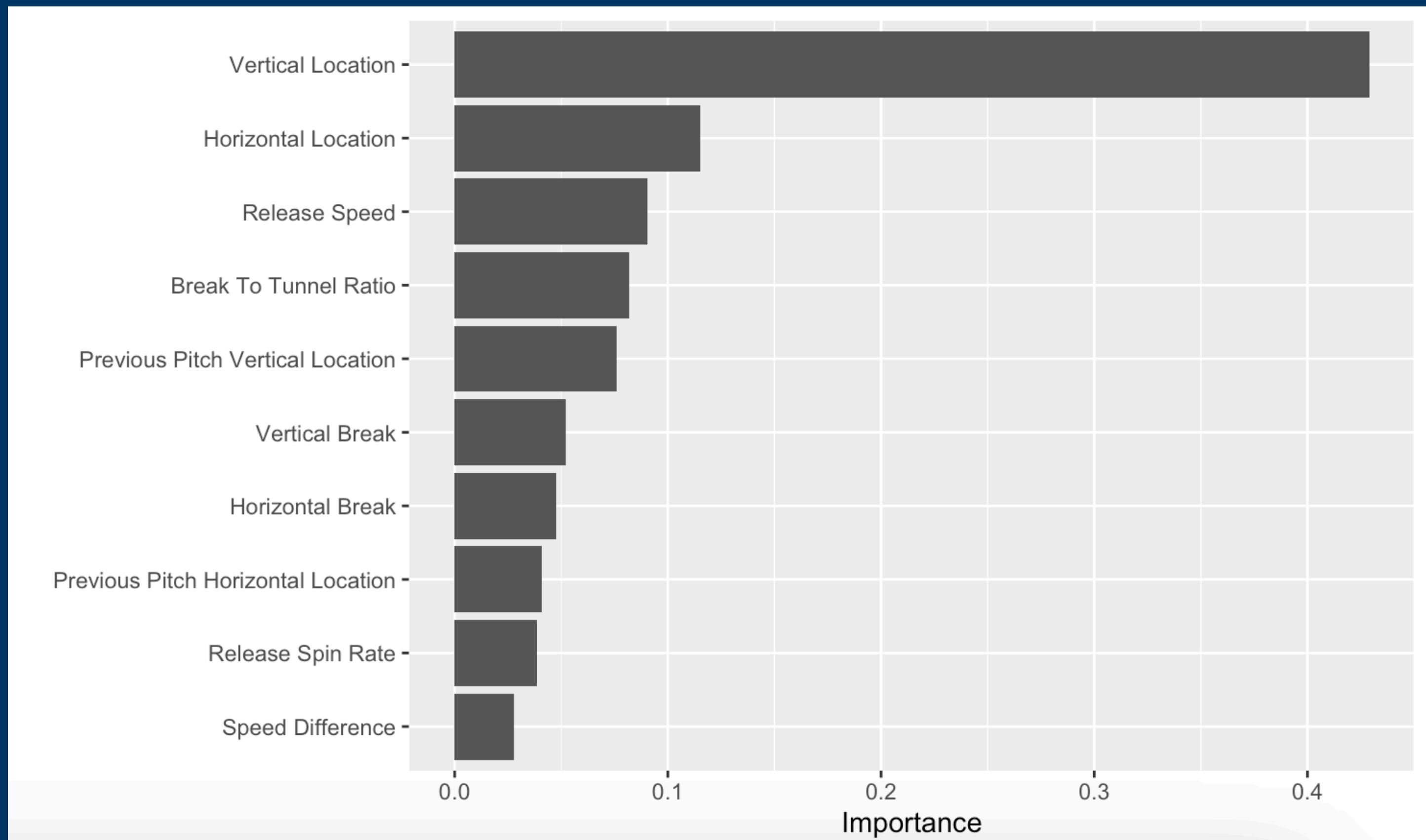


# Four-Seam -> Knuckle Curve | LHP -> RHH | Whiff

**Training Sample: n = 1064 pitches**

**Testing Sample: n = 458 pitches**

**Testing Accuracy: 72.71%**

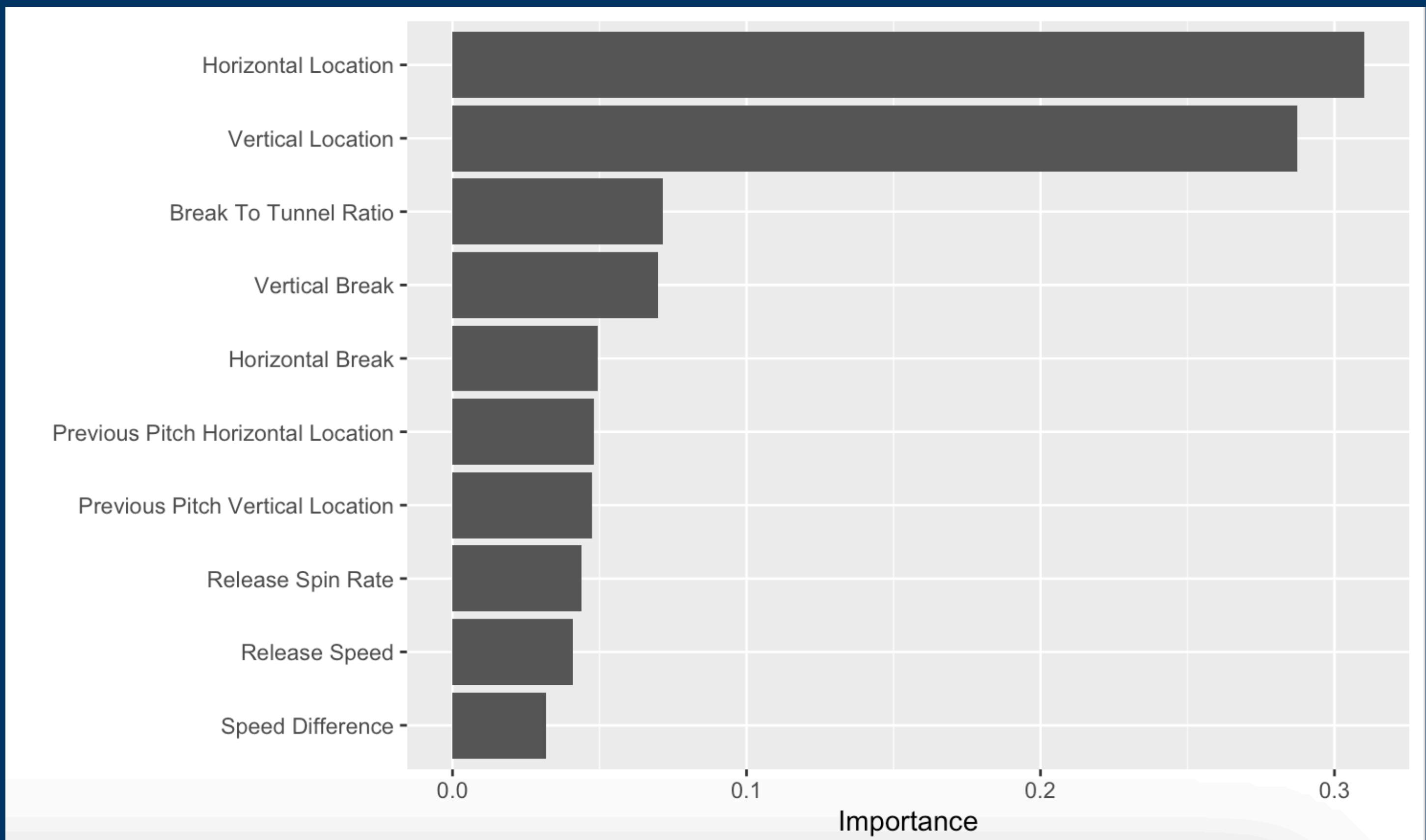


# Four-Seam -> Knuckle Curve | LHP -> RHH | Chase

**Training Sample: n = 1470 pitches**

**Testing Sample: n = 630 pitches**

**Testing Accuracy: 68.41%**

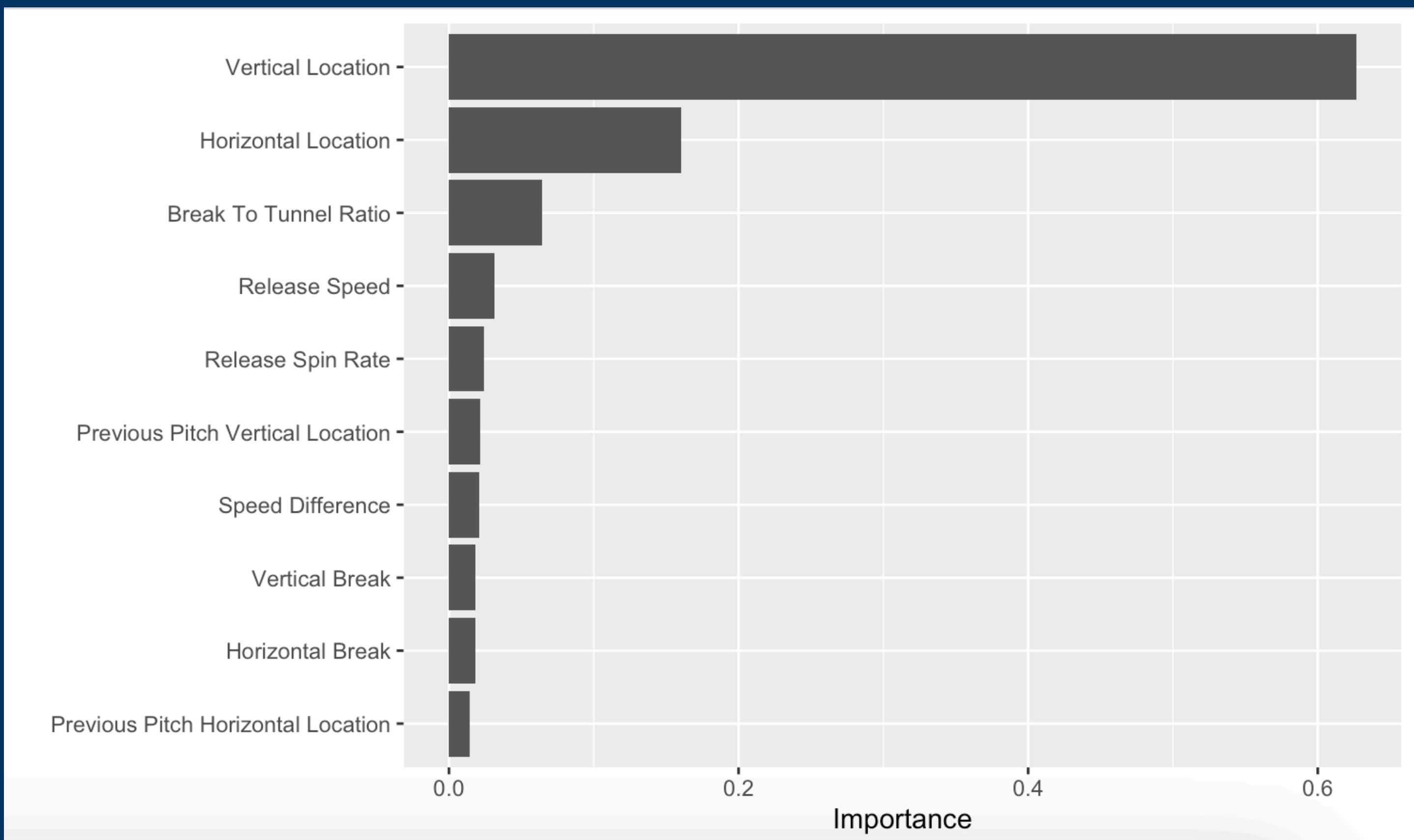


# Four-Seam -> Slider | LHP -> RHH | Whiff

**Training Sample: n = 8568 pitches**

**Testing Sample: n = 3674 pitches**

**Testing Accuracy: 72.21%**

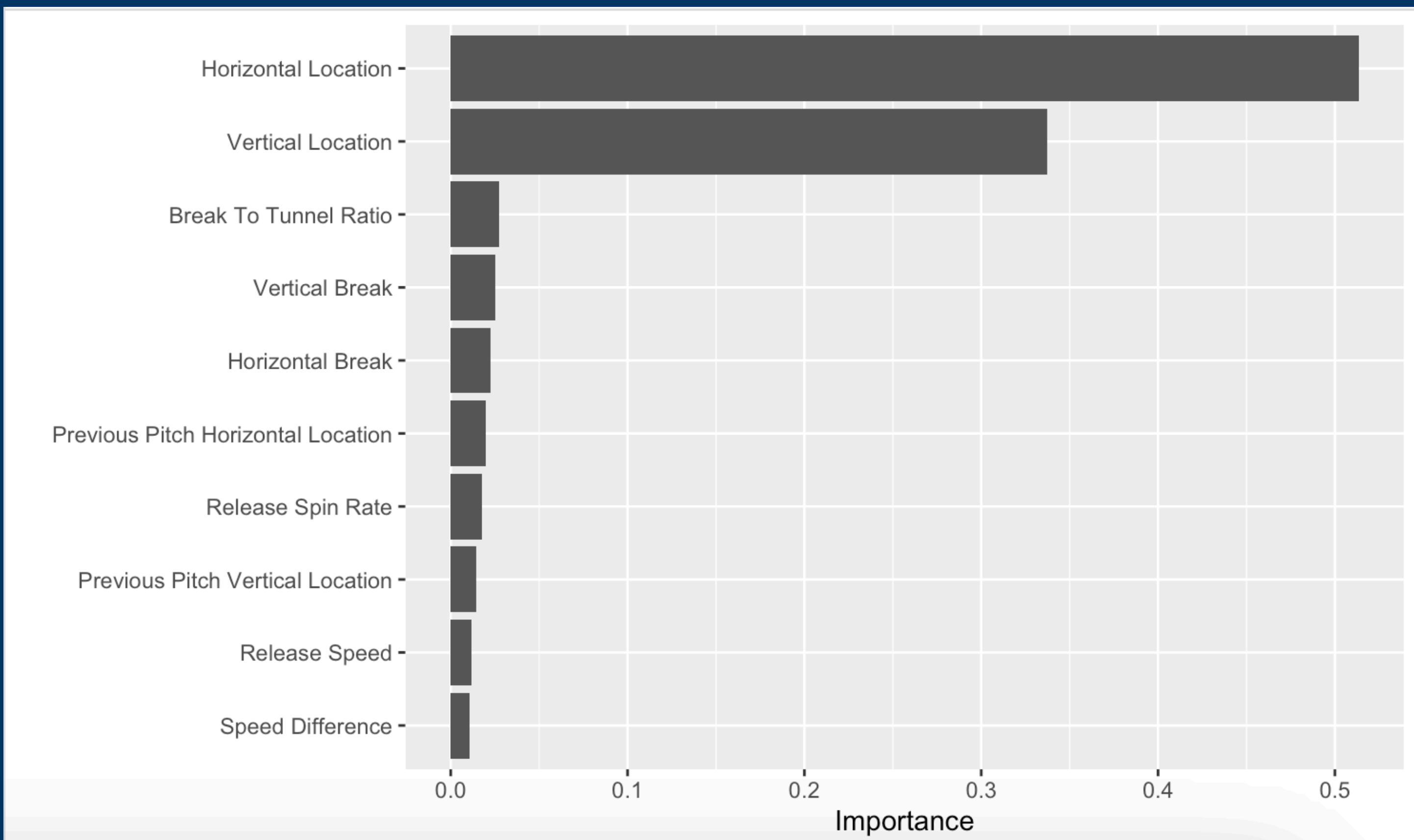


# Four-Seam -> Slider | LHP -> RHH | Chase

**Training Sample: n = 11880 pitches**

**Testing Sample: n = 5092 pitches**

**Testing Accuracy: 70.80%**

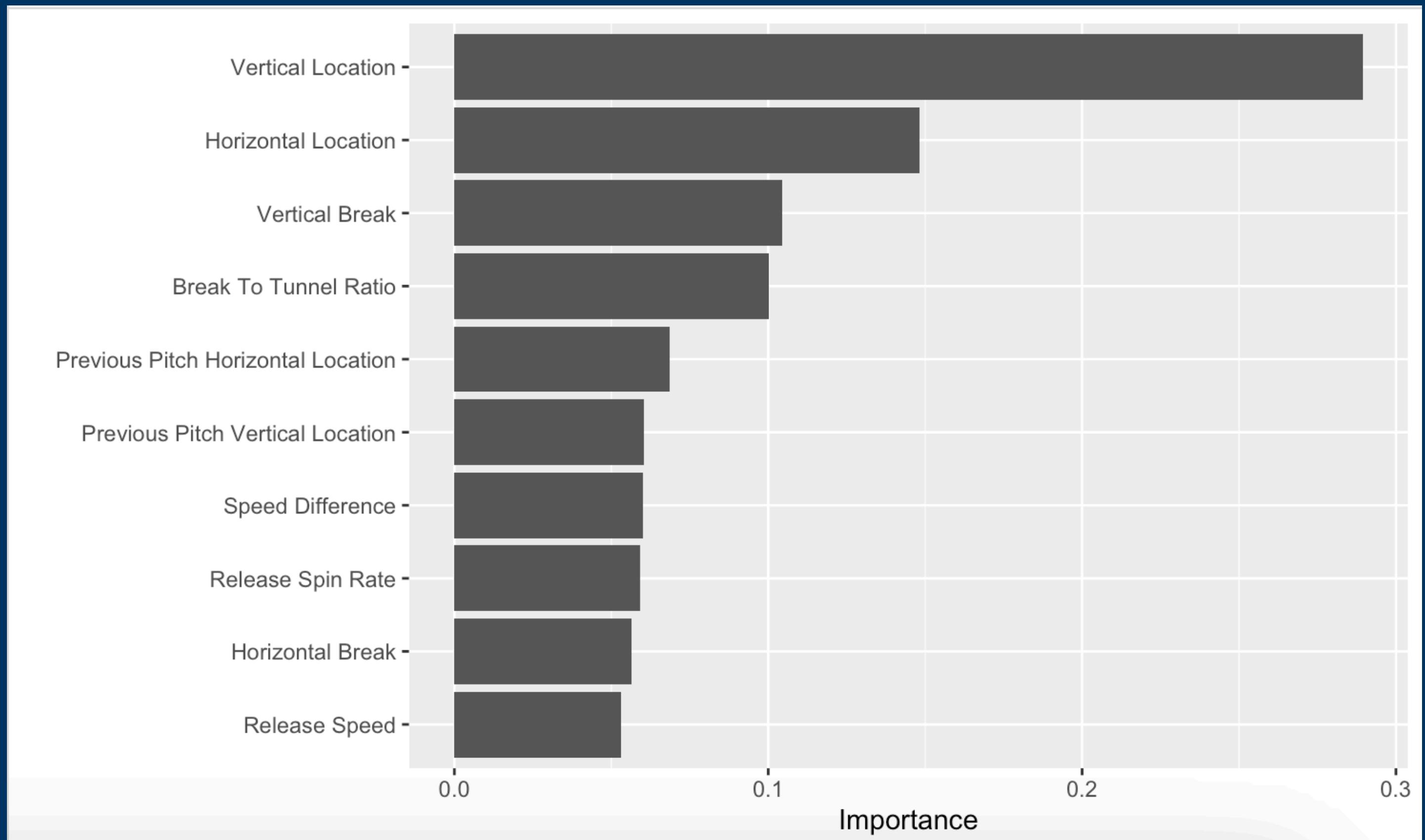


# Four-Seam -> Sweeper | LHP -> RHH | Whiff

**Training Sample: n = 402 pitches**

**Testing Sample: n = 174 pitches**

**Testing Accuracy: 68.97%**

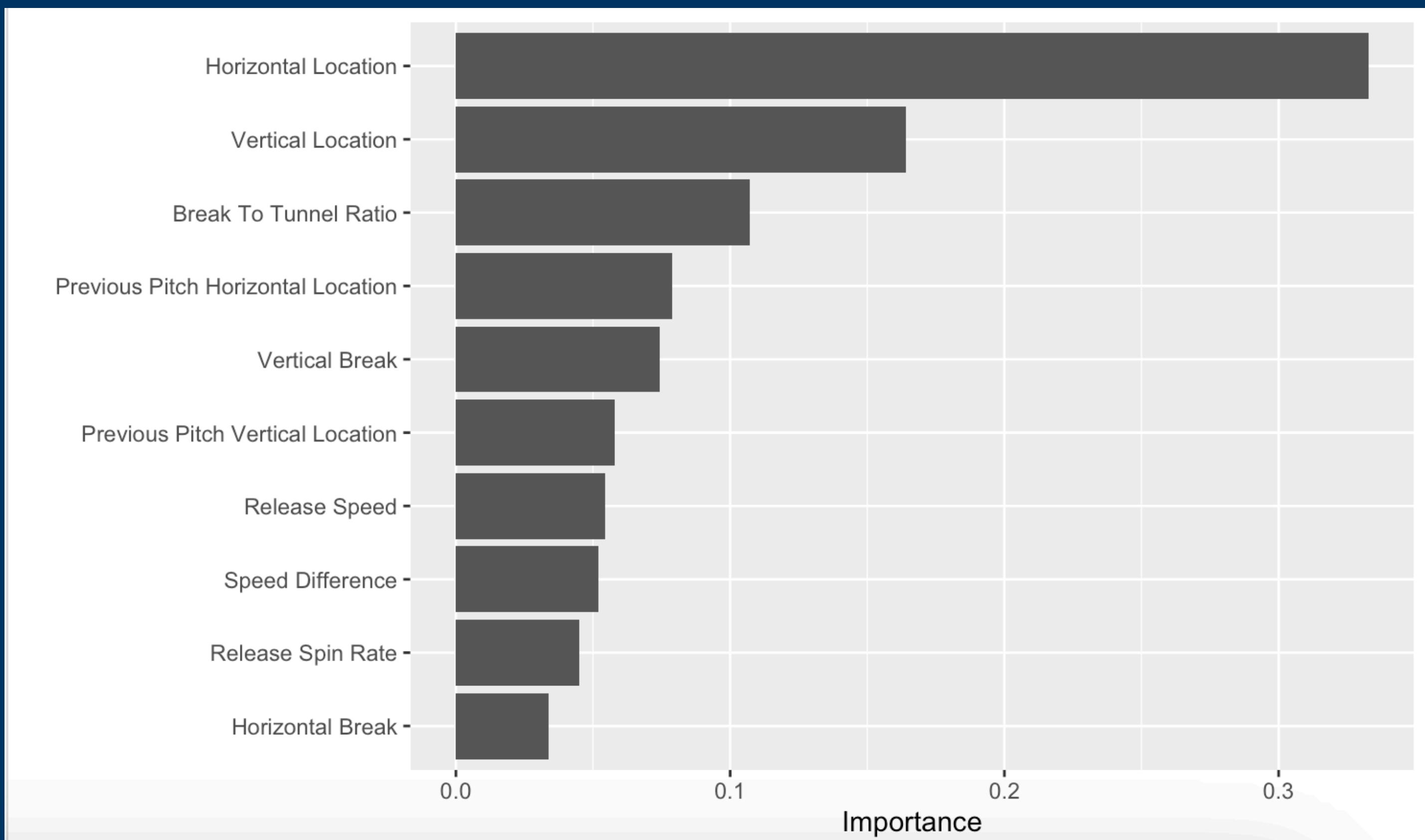


# Four-Seam -> Sweeper | LHP -> RHH | Chase

**Training Sample: n = 646 pitches**

**Testing Sample: n = 278 pitches**

**Testing Accuracy: 68.71%**

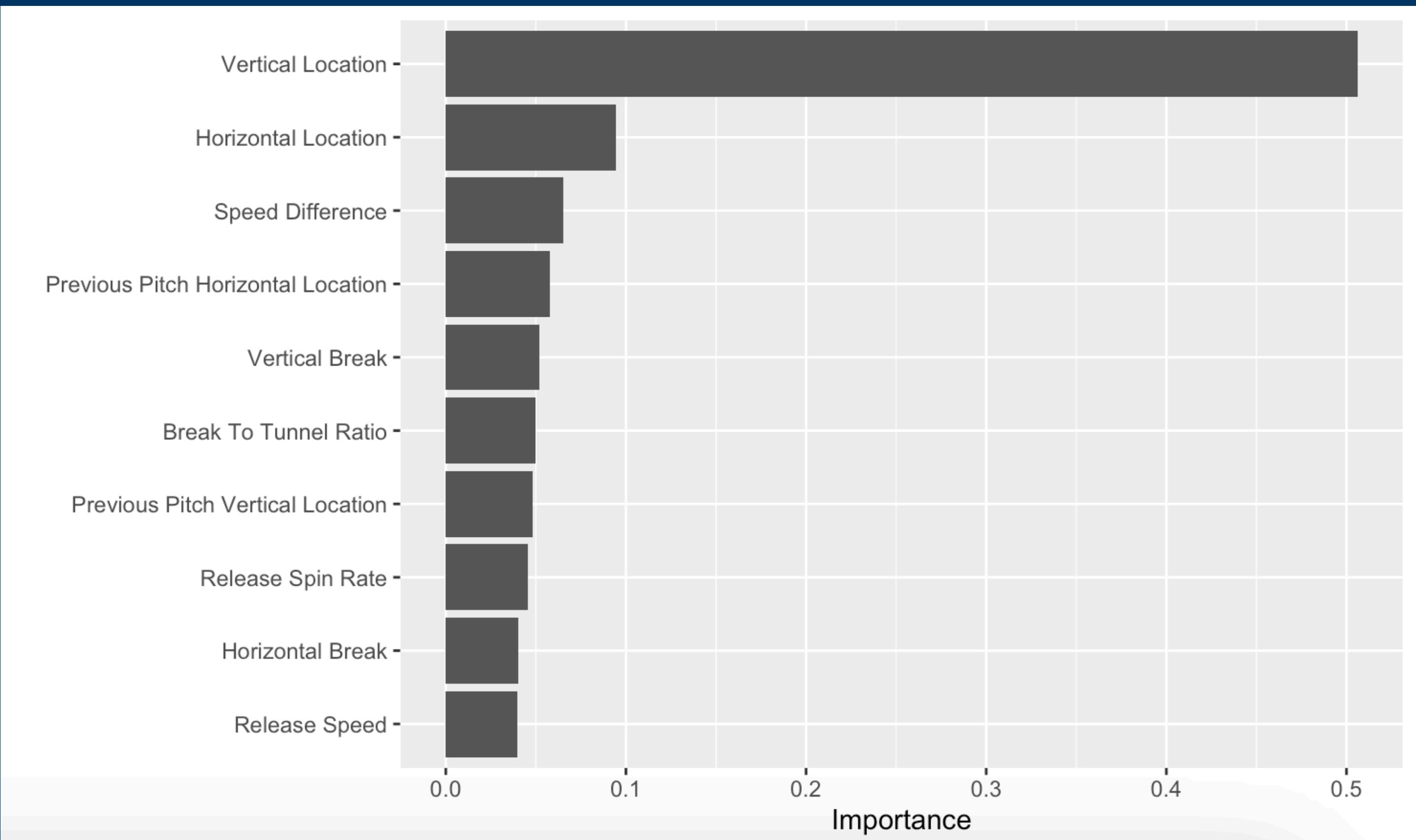


# Sinker -> Changeup | LHP -> RHH | Whiff

**Training Sample: n = 6102 pitches**

**Testing Sample: n = 2616 pitches**

**Testing Accuracy: 63.49%**

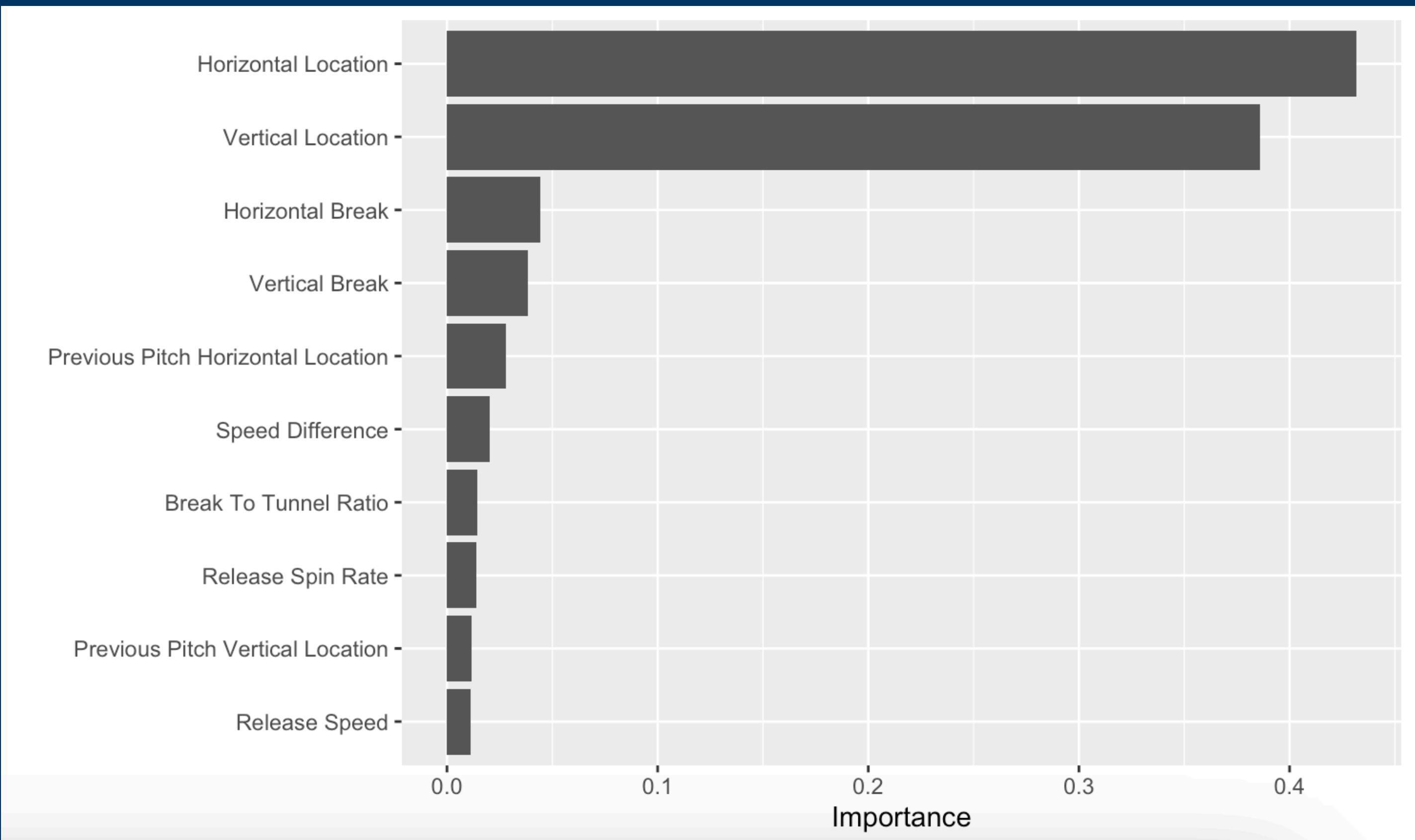


# Sinker -> Changeup | LHP -> RHH | Chase

**Training Sample: n = 10068 pitches**

**Testing Sample: n = 4316 pitches**

**Testing Accuracy: 71.76%**

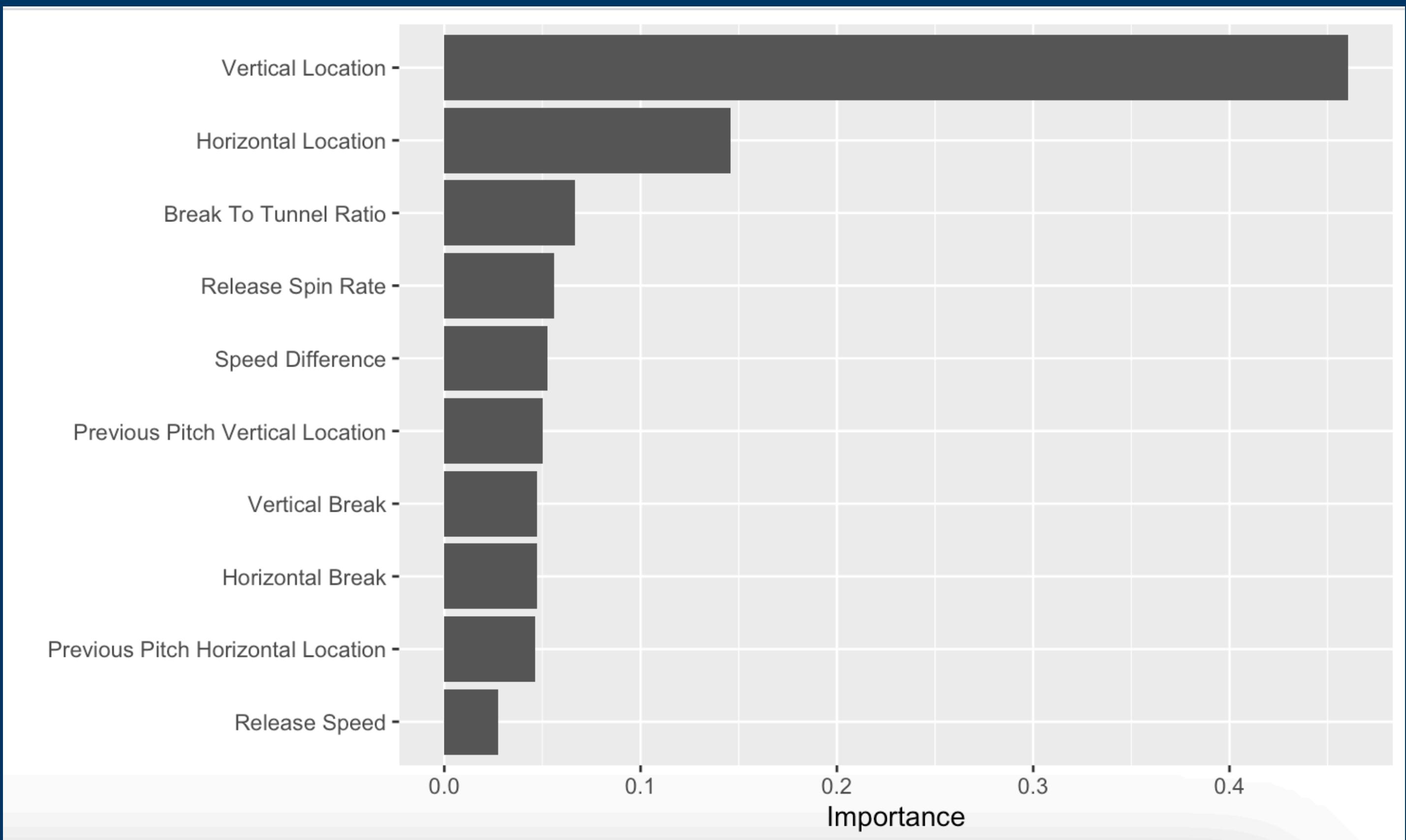


# Sinker -> Curveball | LHP -> RHH | Whiff

**Training Sample: n = 1936 pitches**

**Testing Sample: n = 832 pitches**

**Testing Accuracy: 72.72%**

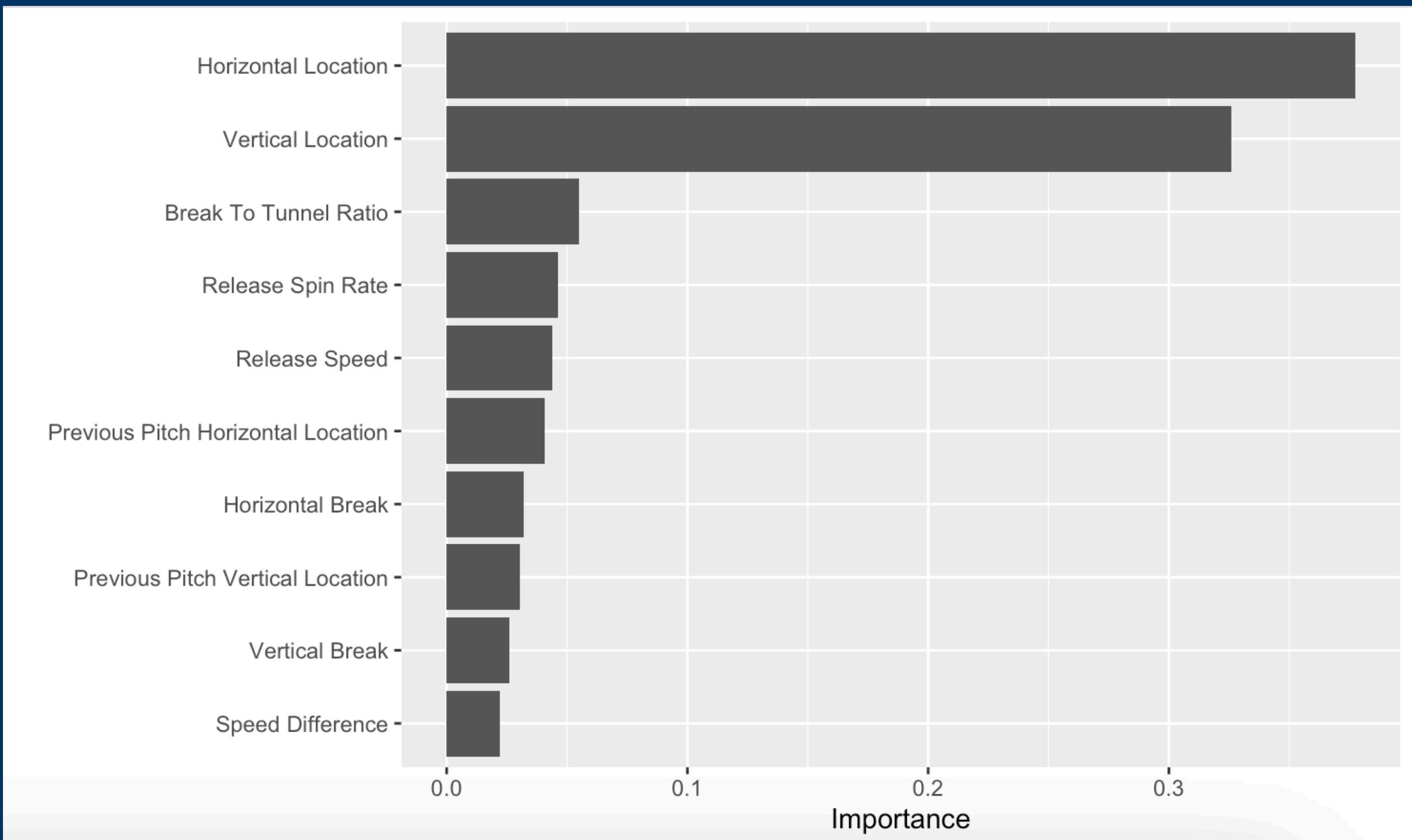


# Sinker -> Curveball | LHP -> RHH | Chase

**Training Sample: n = 2776 pitches**

**Testing Sample: n = 1190 pitches**

**Testing Accuracy: 72.18%**

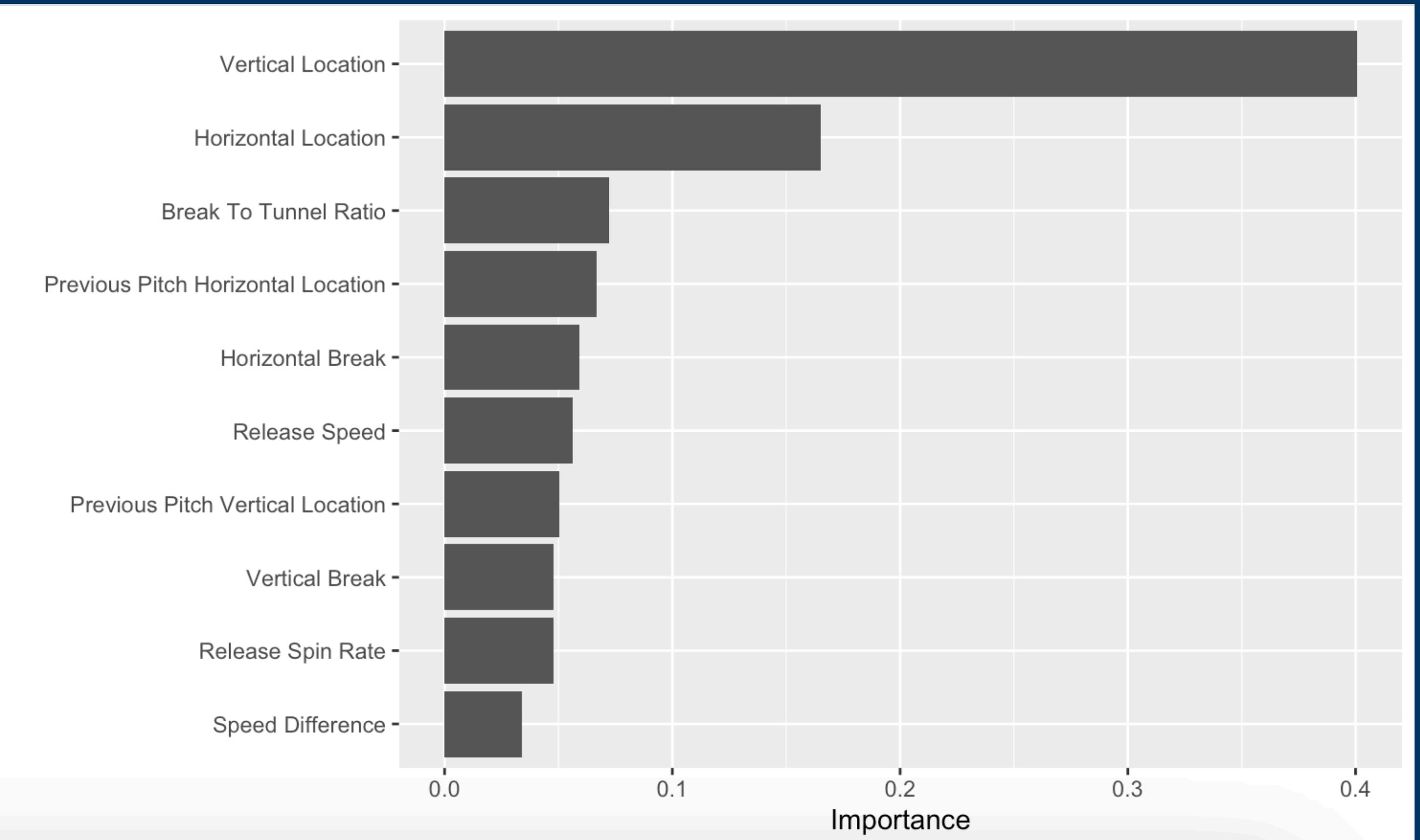


# Sinker -> Knuckle Curve | LHP -> RHH | Whiff

**Training Sample: n = 704 pitches**

**Testing Sample: n = 304 pitches**

**Testing Accuracy: 67.11%**

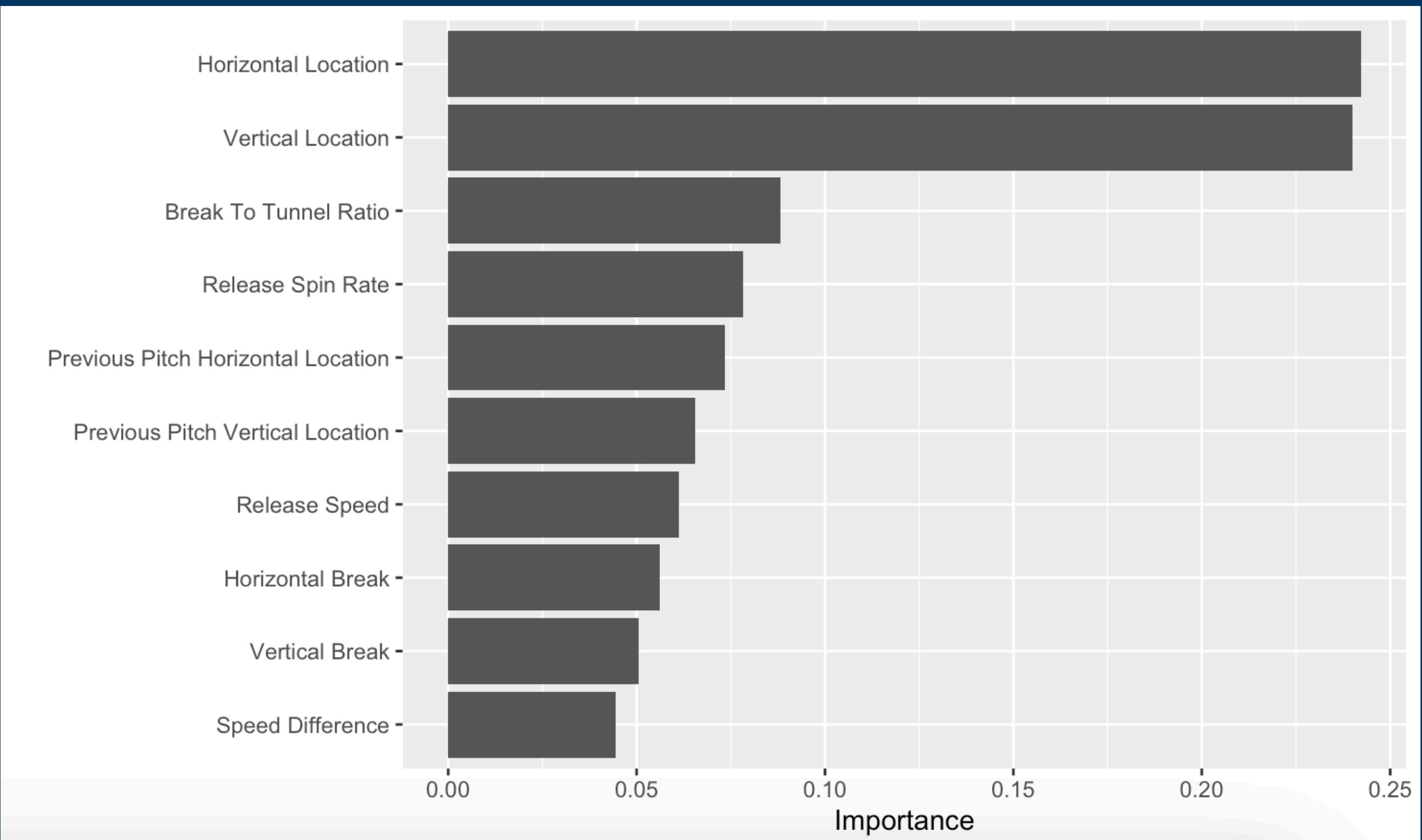


# Sinker -> Knuckle Curve | LHP -> RHH | Chase

**Training Sample: n = 1026 pitches**

**Testing Sample: n = 442 pitches**

**Testing Accuracy: 70.36%**

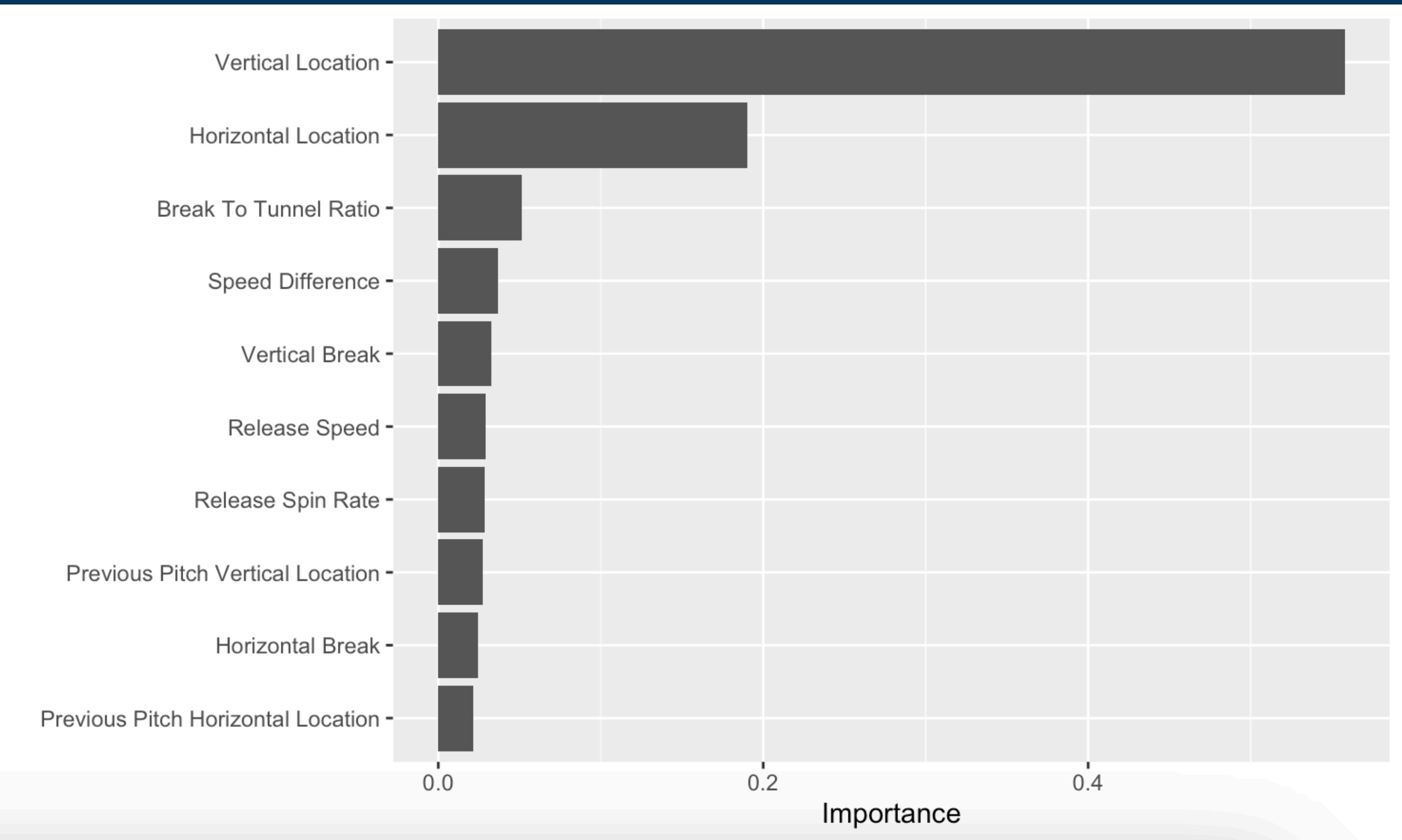


# Sinker -> Slider | LHP -> RHH | Whiff

**Training Sample: n = 3818 pitches**

**Testing Sample: n = 1638 pitches**

**Testing Accuracy: 71.73%**

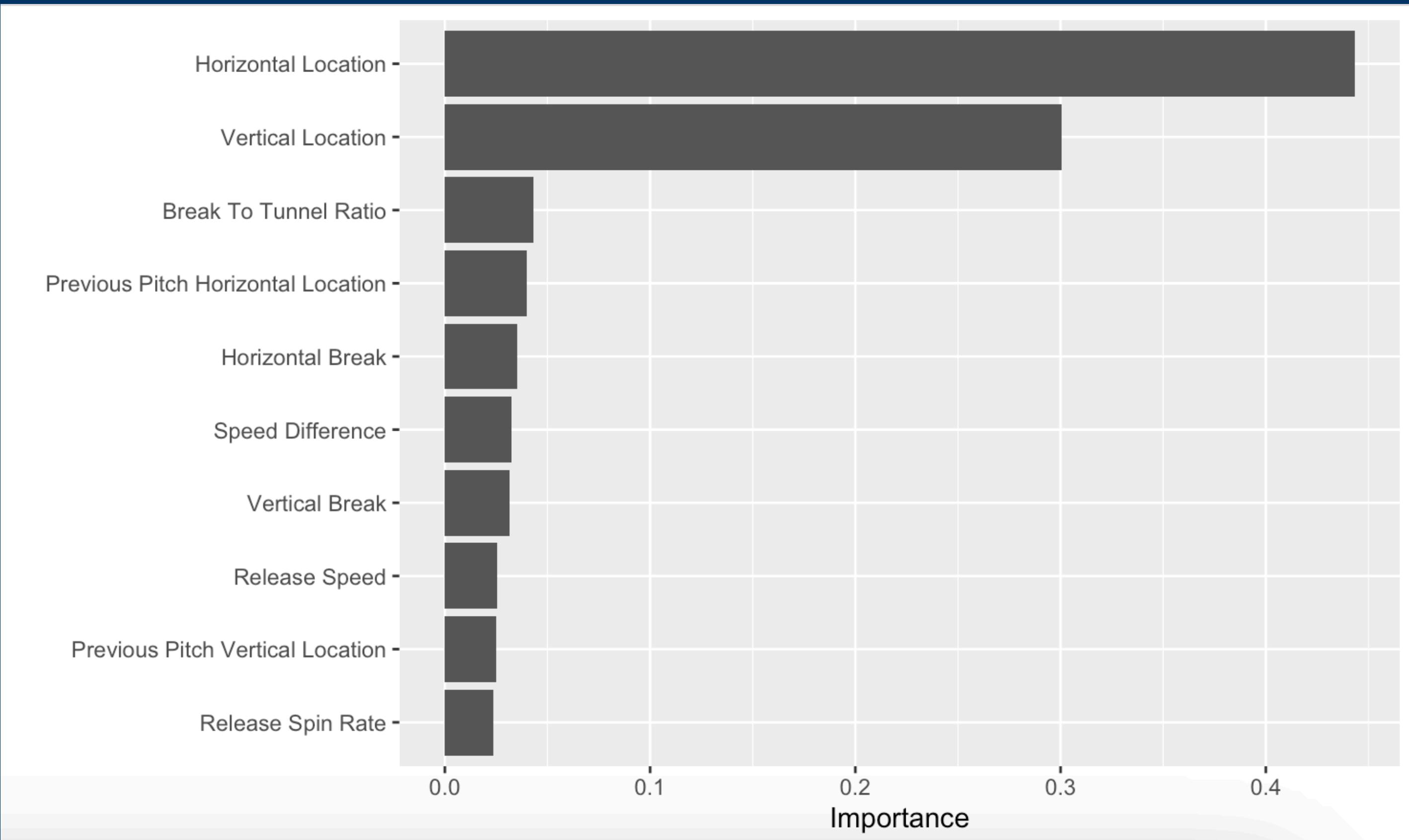


# Sinker -> Slider | LHP -> RHH | Chase

**Training Sample: n = 5346 pitches**

**Testing Sample: n = 2292 pitches**

**Testing Accuracy: 70.99%**

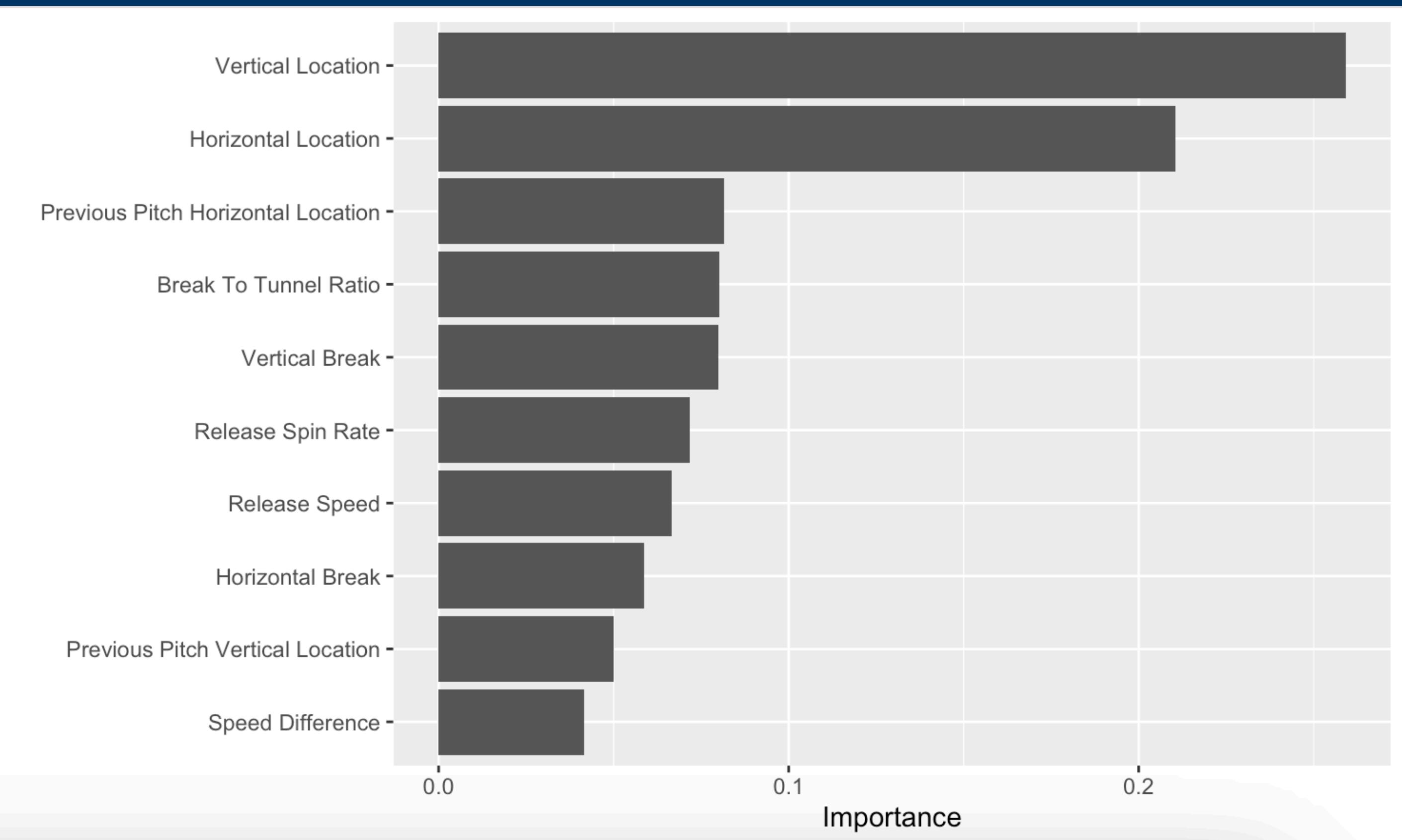


# Sinker -> Sweeper | LHP -> RHH | Whiff

**Training Sample: n = 246 pitches**

**Testing Sample: n = 106 pitches**

**Testing Accuracy: 66.04%**

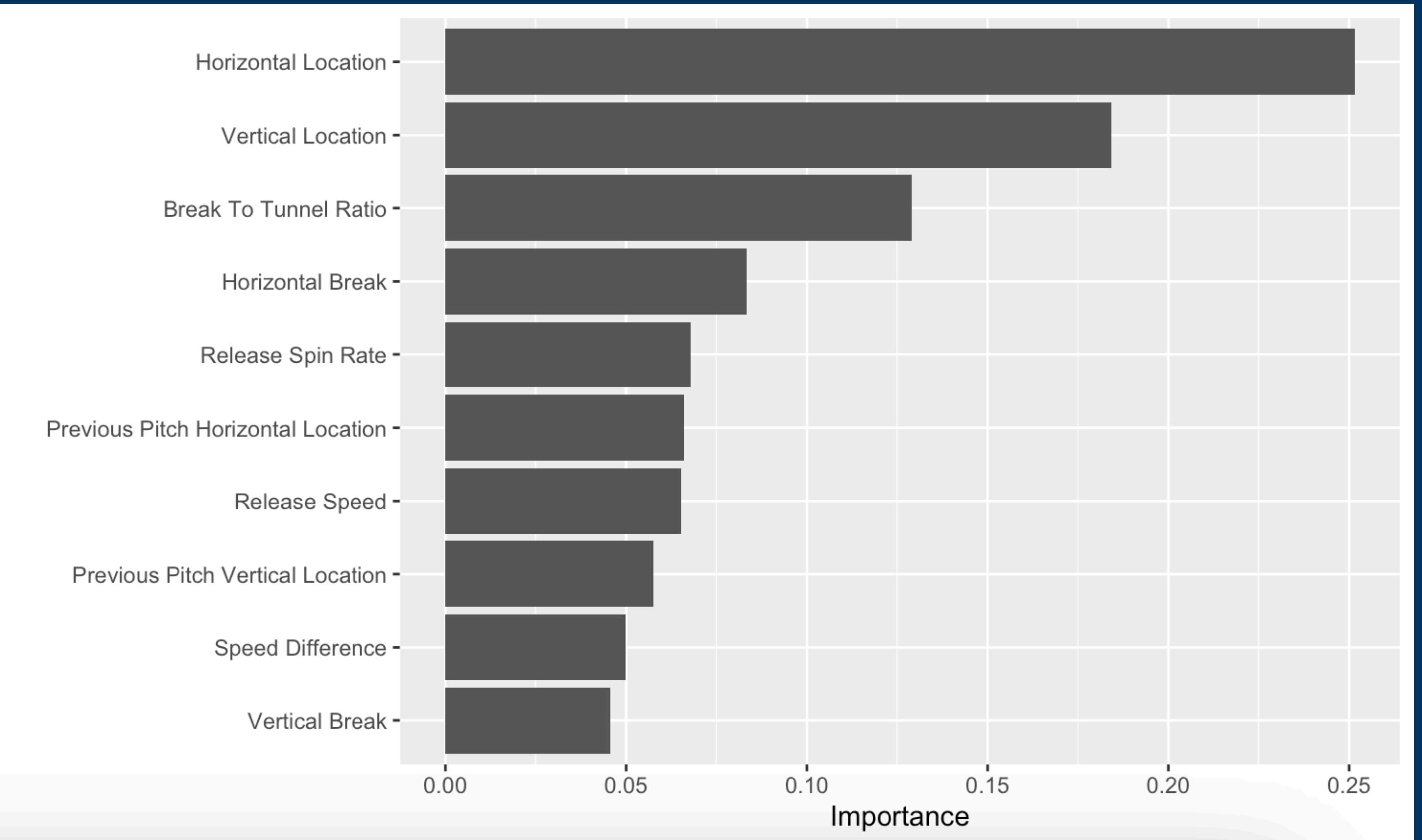


# Sinker -> Sweeper | LHP -> RHH | Chase

**Training Sample: n = 400 pitches**

**Testing Sample: n = 174 pitches**

**Testing Accuracy: 67.82%**



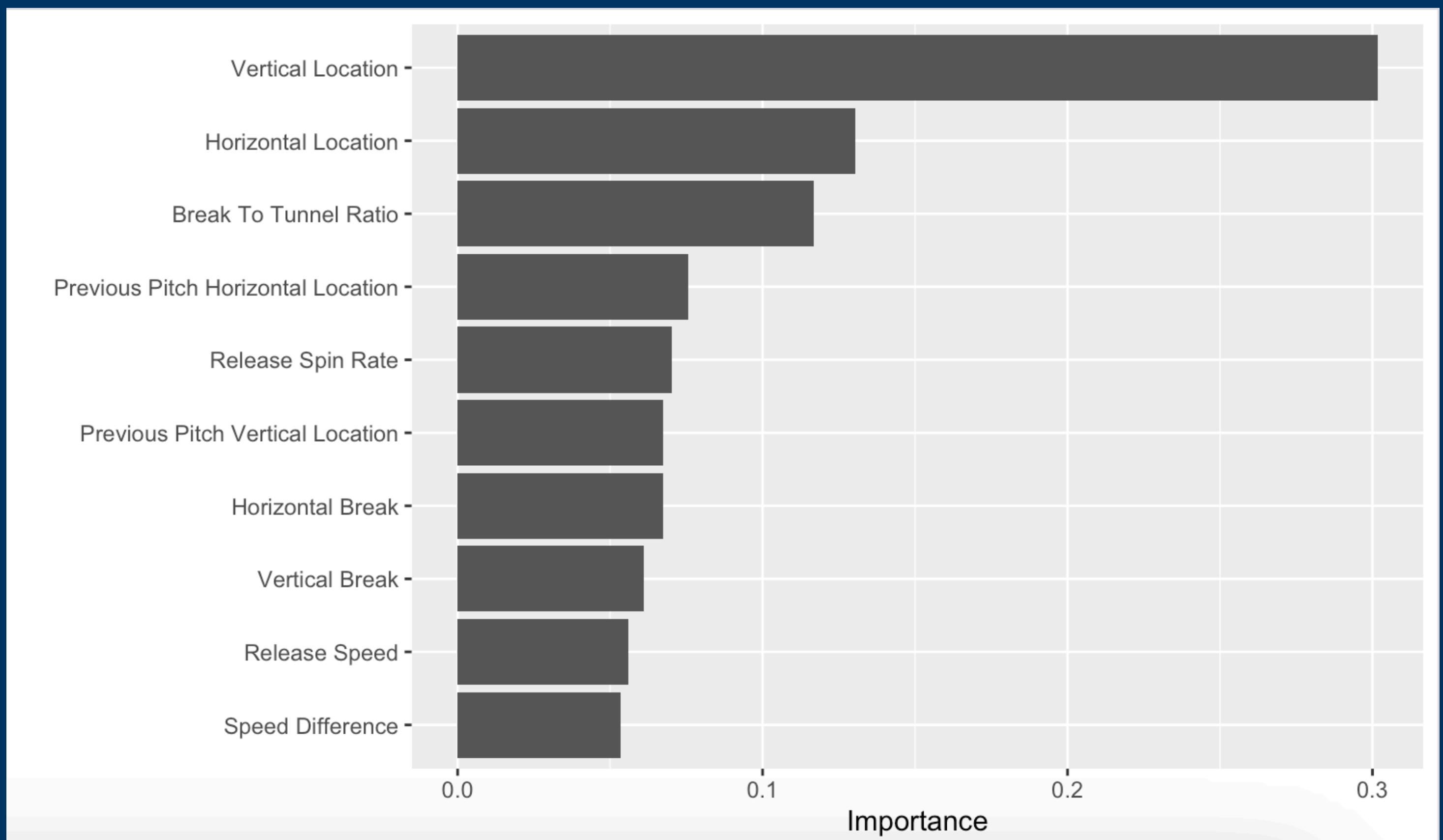
# Left Handed Pitchers vs Left Handed Hitters

# Cutter -> Changeup | LHP -> LHH | Whiff

**Training Sample: n = 246 pitches**

**Testing Sample: n = 106 pitches**

**Testing Accuracy: 75.47%**

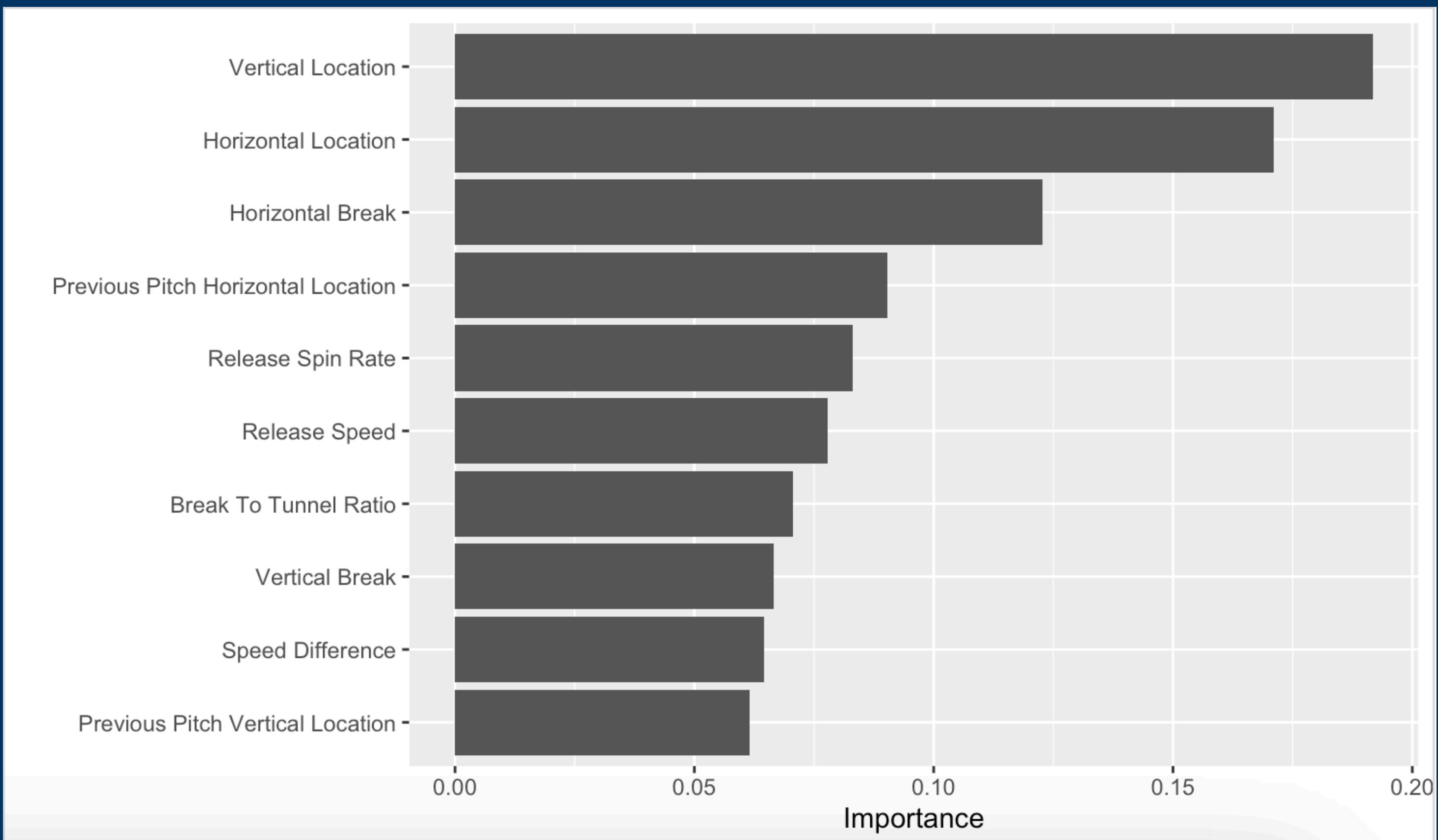


# Cutter -> Changeup | LHP -> LHH | Chase

**Training Sample: n = 322 pitches**

**Testing Sample: n = 140 pitches**

**Testing Accuracy: 67.86%**

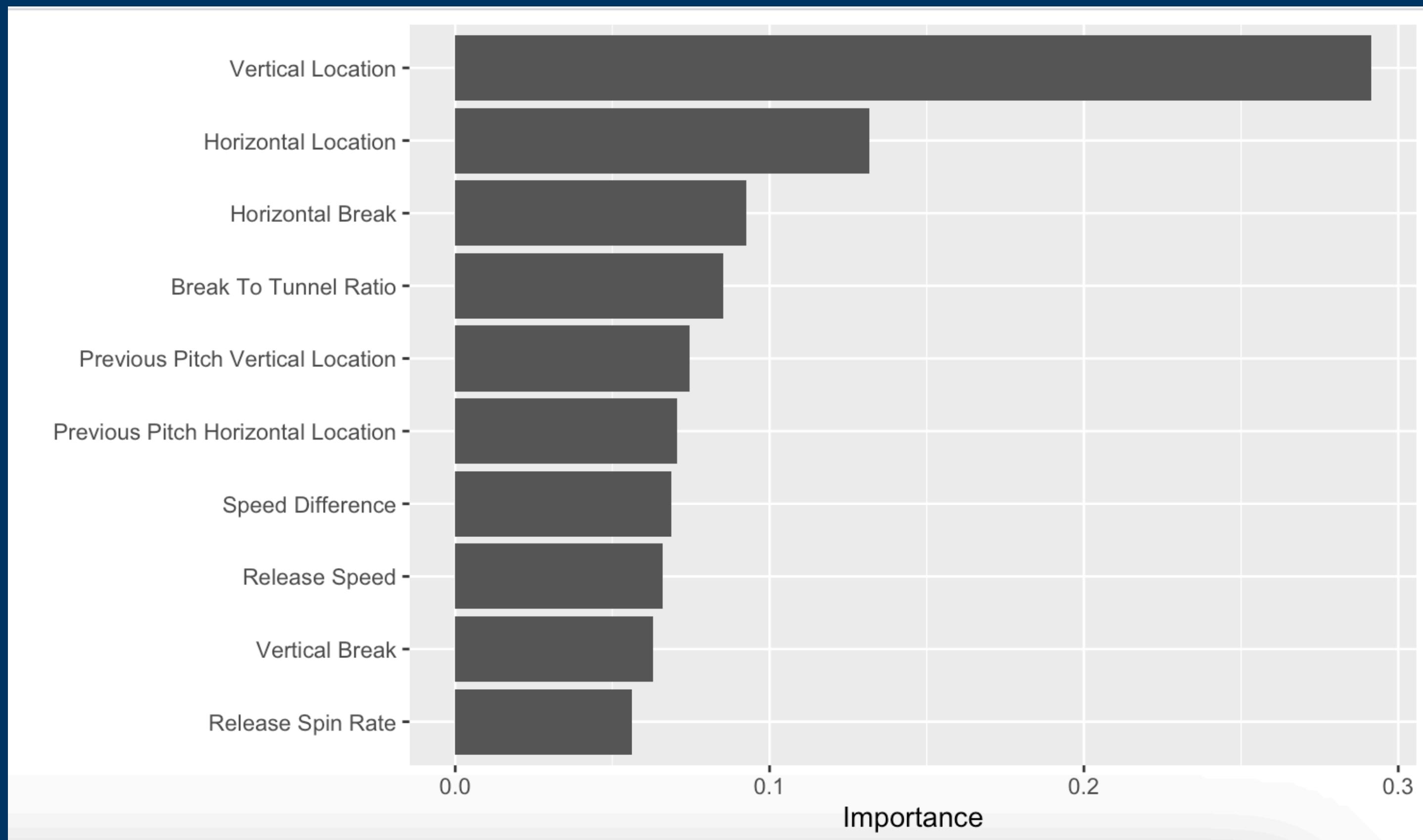


# Cutter -> Curveball | LHP -> LHH | Whiff

**Training Sample: n = 384 pitches**

**Testing Sample: n = 166 pitches**

**Testing Accuracy: 69.88%**

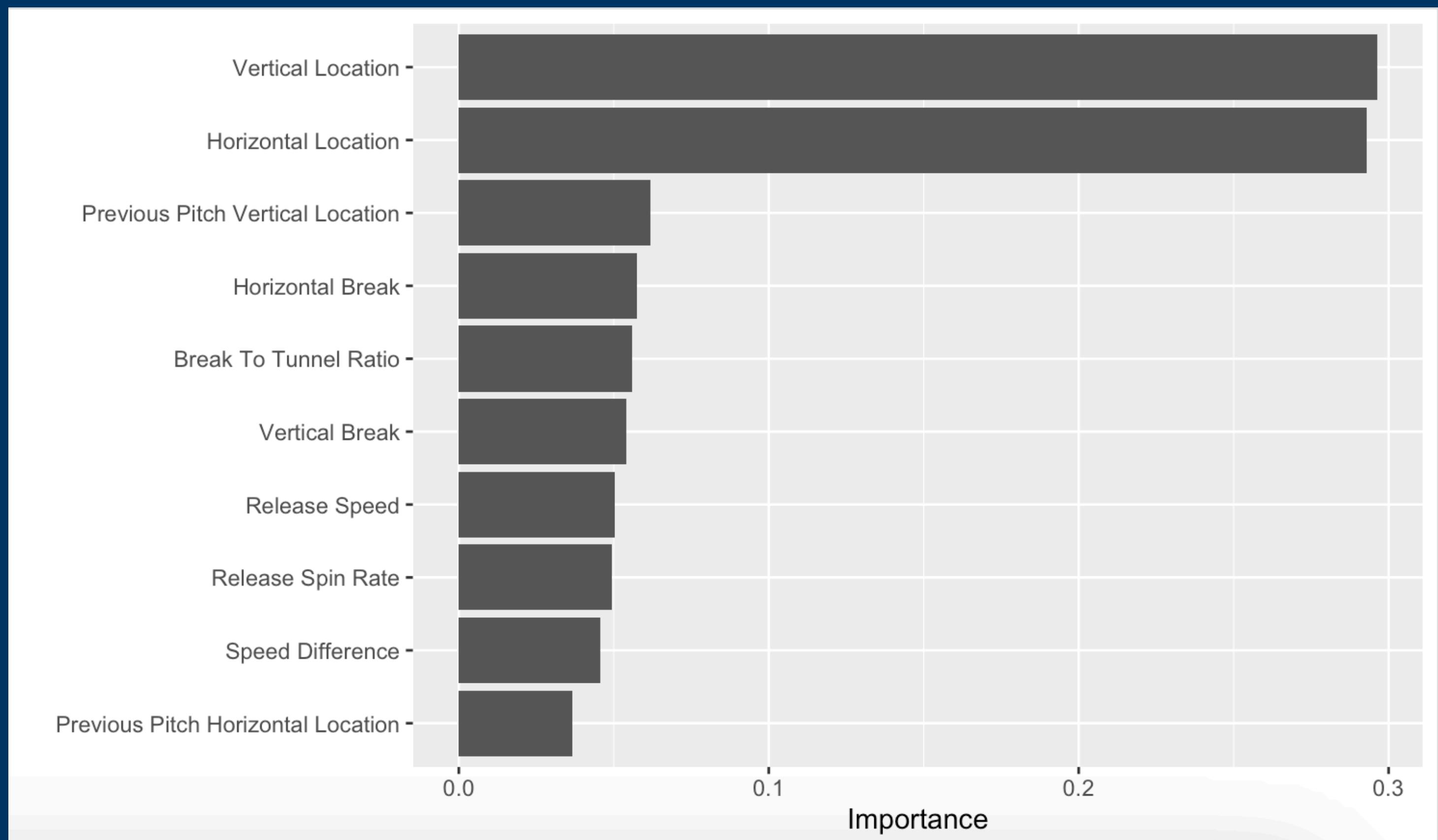


# Cutter -> Curveball | LHP -> LHH | Chase

**Training Sample: n = 504 pitches**

**Testing Sample: n = 218 pitches**

**Testing Accuracy: 76.61%**

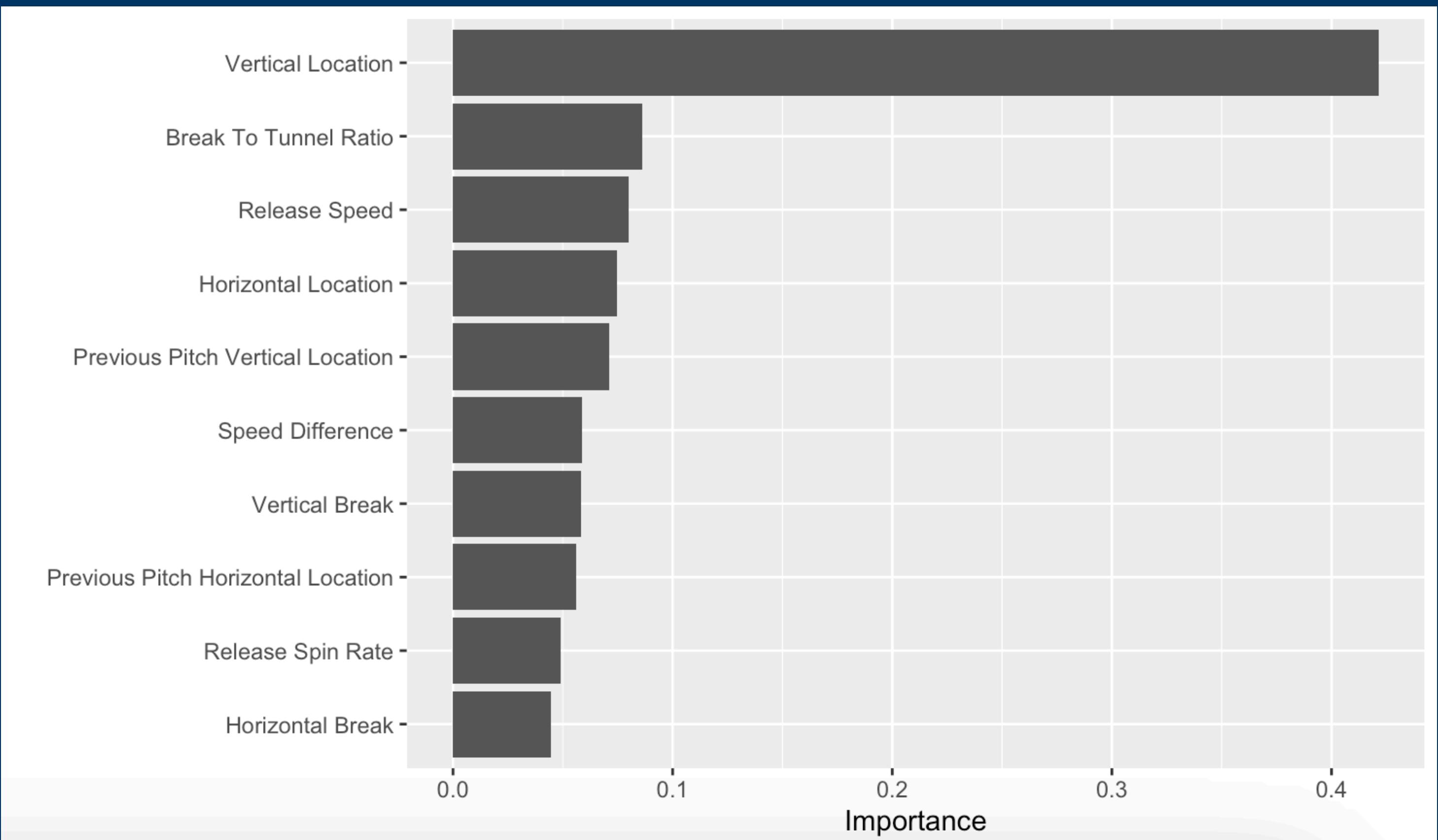


# Four-Seam -> Changeup | LHP -> LHH | Whiff

**Training Sample: n = 1064 pitches**

**Testing Sample: n = 456 pitches**

**Testing Accuracy: 69.30%**

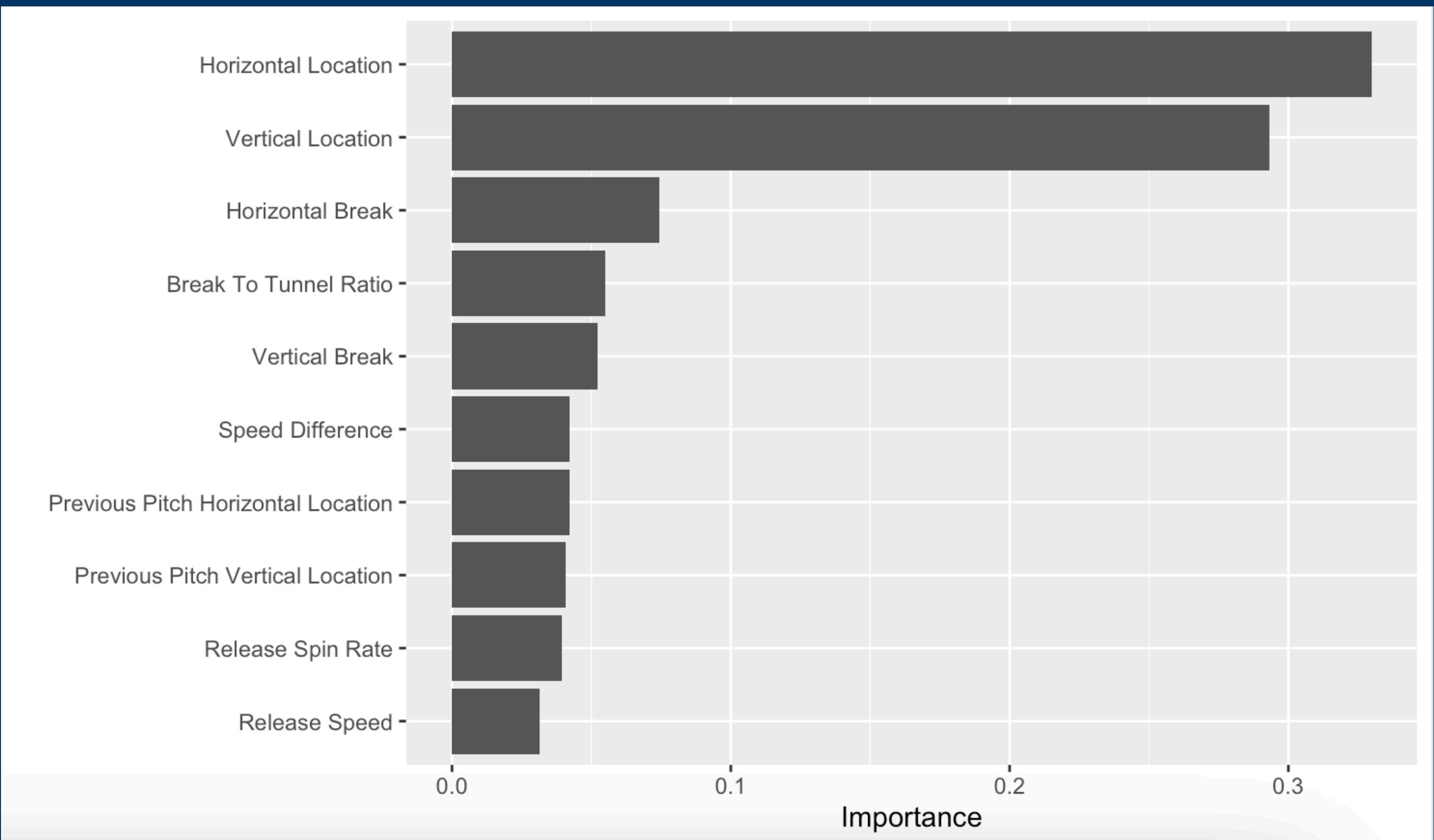


# Four-Seam -> Changeup | LHP -> LHH | Chase

**Training Sample: n = 1354 pitches**

**Testing Sample: n = 582 pitches**

**Testing Accuracy: 69.59%**

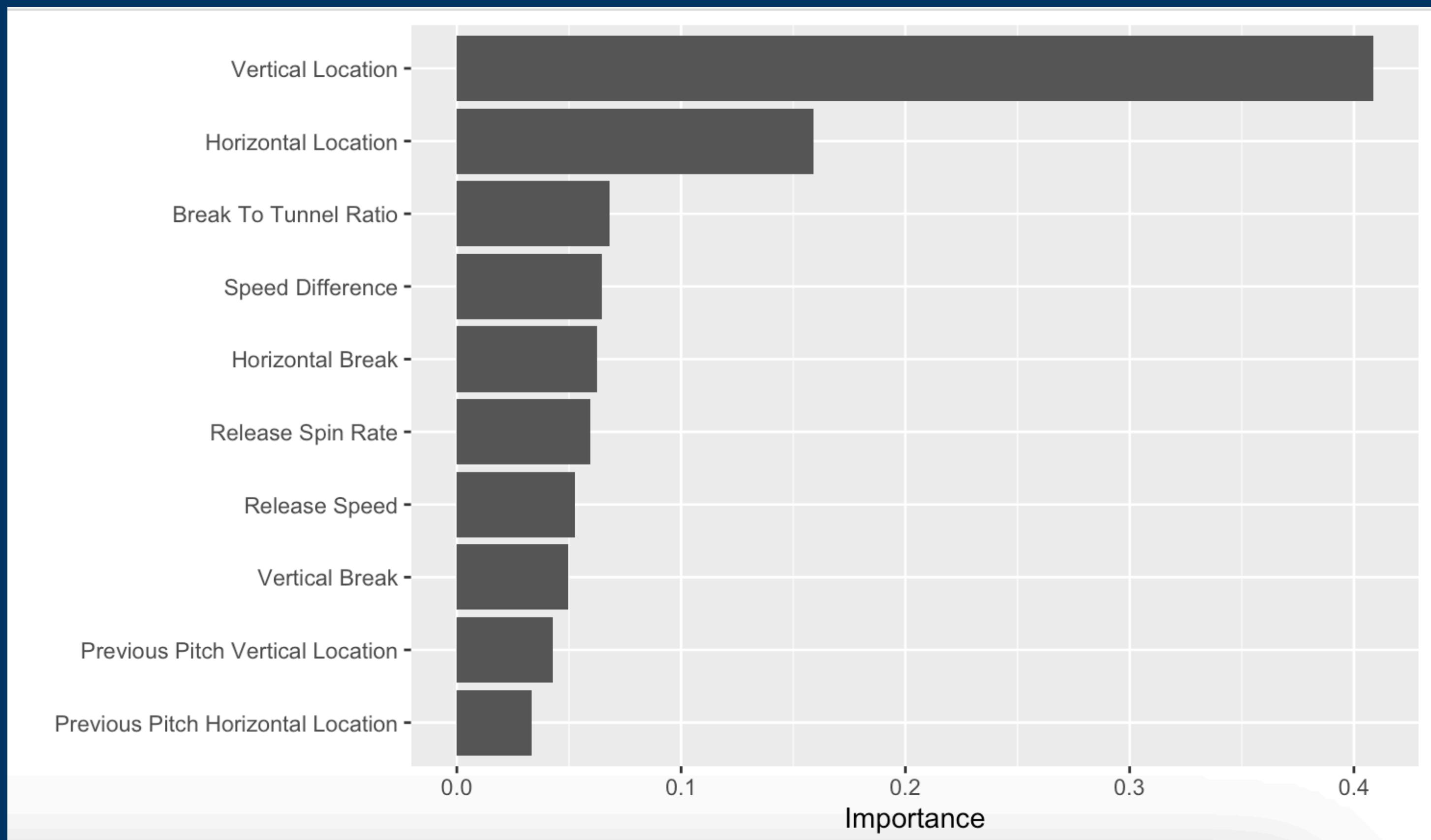


# Four-Seam -> Curveball | LHP -> LHH | Whiff

**Training Sample: n = 1736 pitches**

**Testing Sample: n = 746 pitches**

**Testing Accuracy: 71.72%**

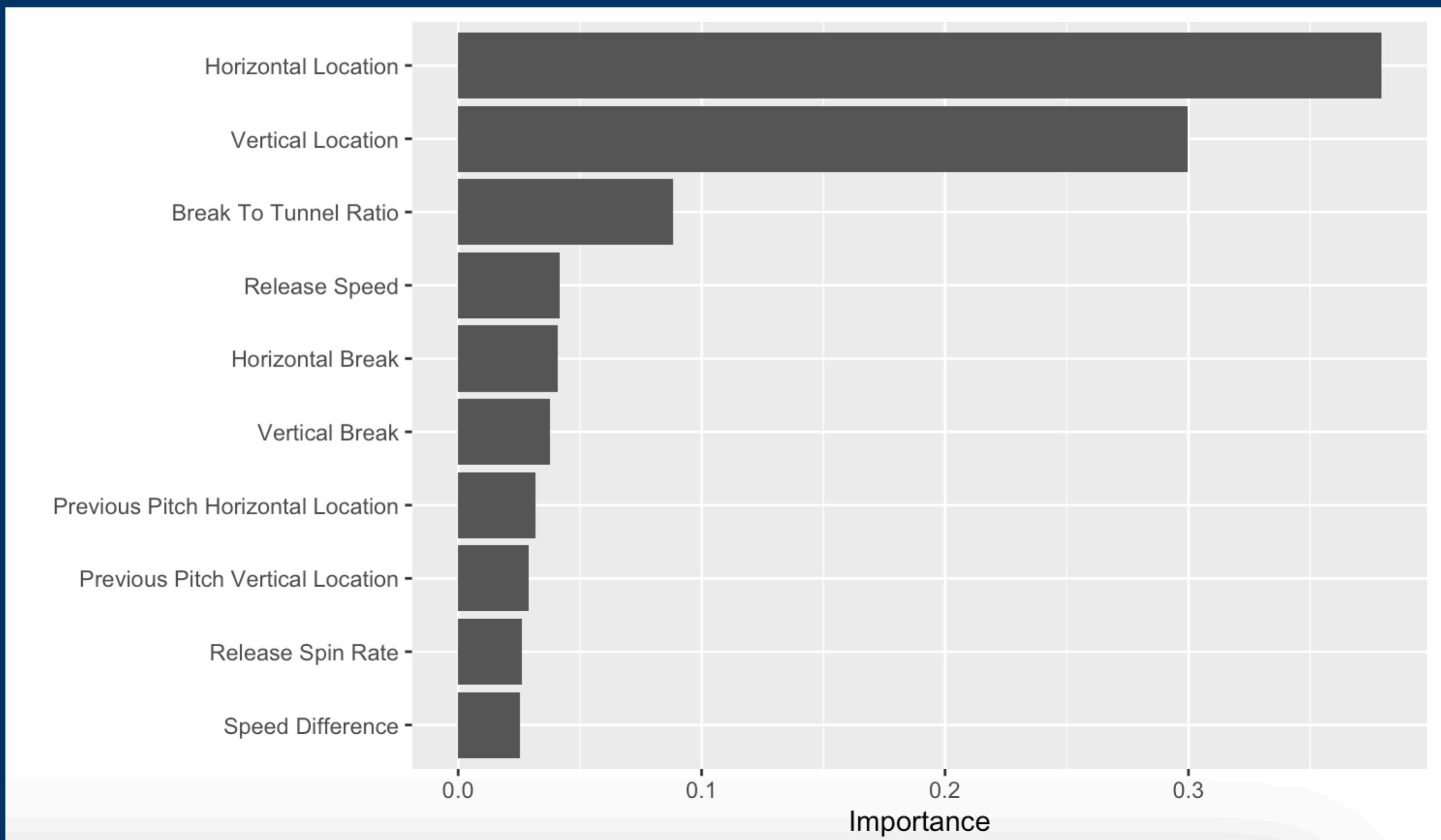


# Four-Seam -> Curveball | LHP -> LHH | Chase

**Training Sample: n = 2558 pitches**

**Testing Sample: n = 1098 pitches**

**Testing Accuracy: 72.59%**

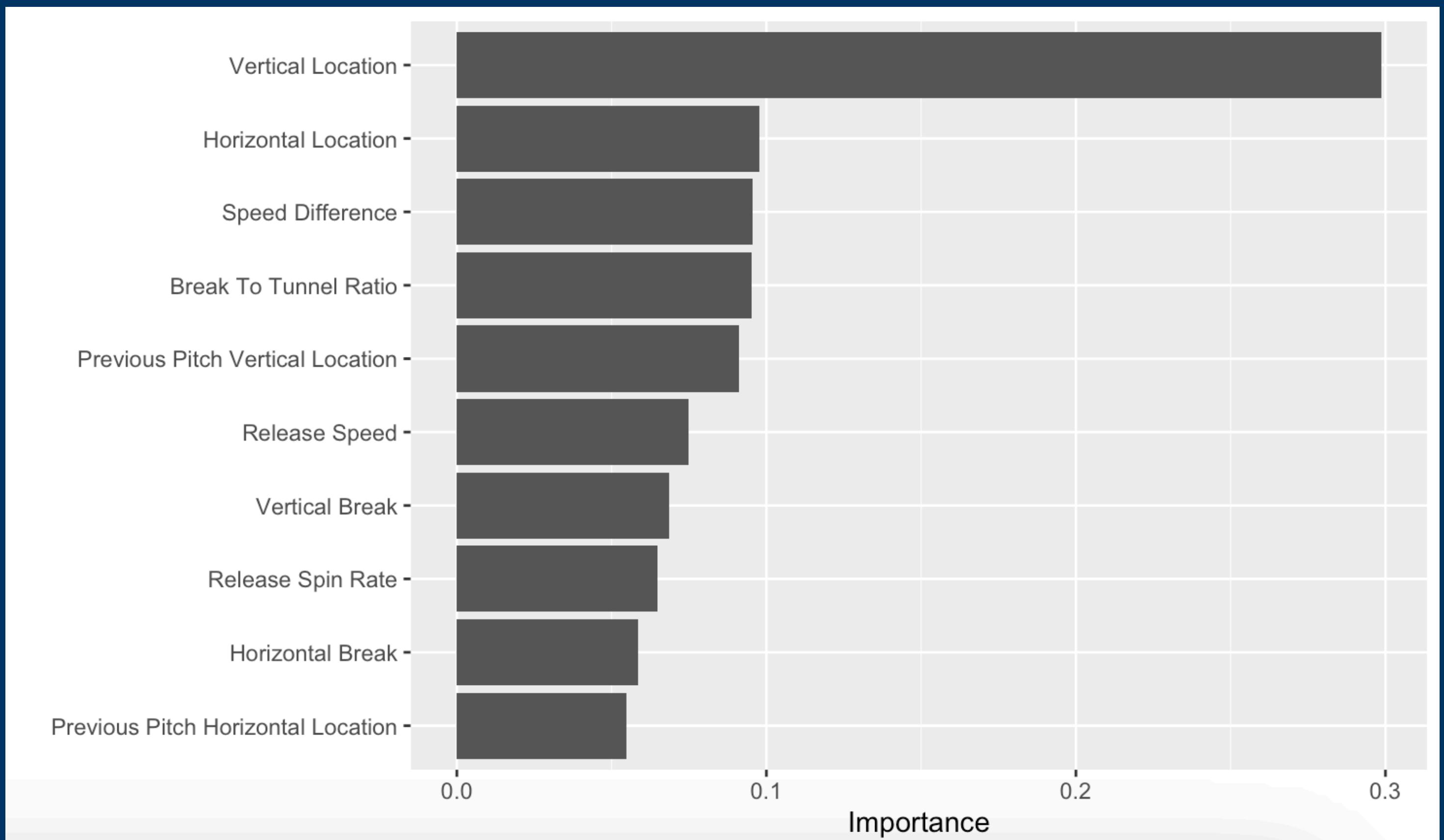


# Four-Seam -> Knuckle Curve | LHP -> LHH | Whiff

**Training Sample: n = 274 pitches**

**Testing Sample: n = 120 pitches**

**Testing Accuracy: 75.83%**

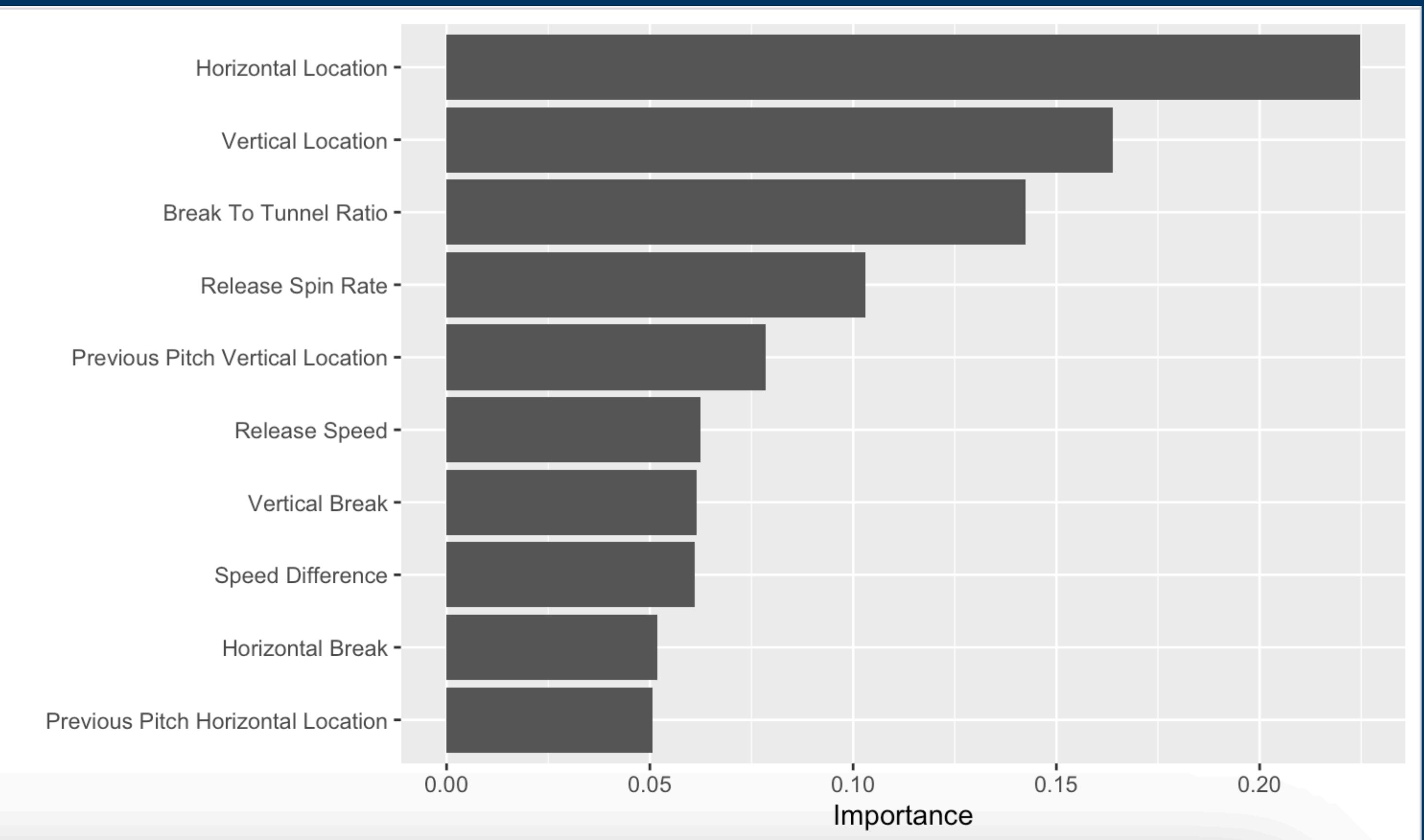


# Four-Seam -> Knuckle Curve | LHP -> LHH | Chase

**Training Sample: n = 434 pitches**

**Testing Sample: n = 188 pitches**

**Testing Accuracy: 71.28%**

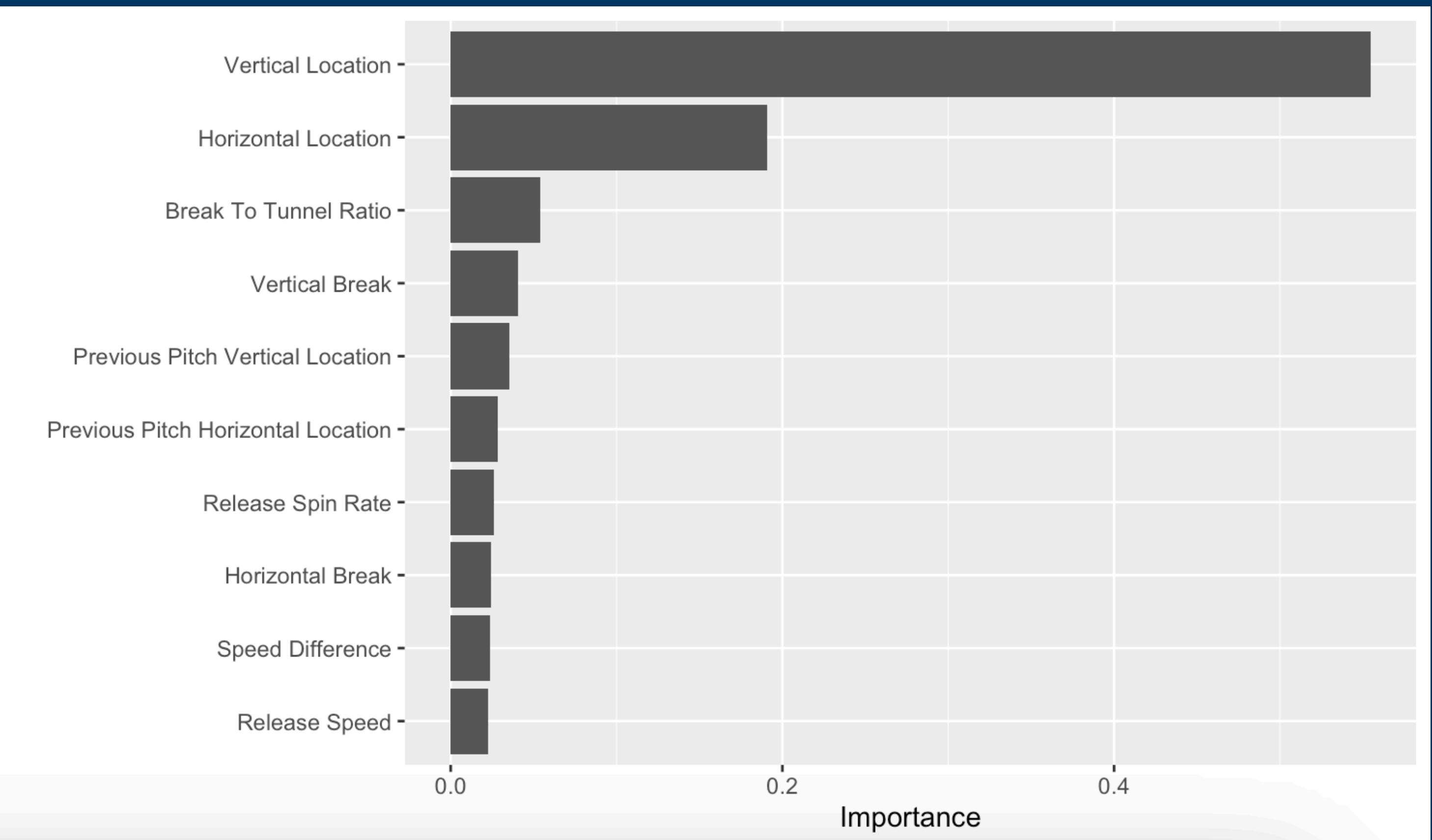


# Four-Seam -> Slider | LHP -> LHH | Whiff

**Training Sample: n = 5286 pitches**

**Testing Sample: n = 2266 pitches**

**Testing Accuracy: 68.27%**

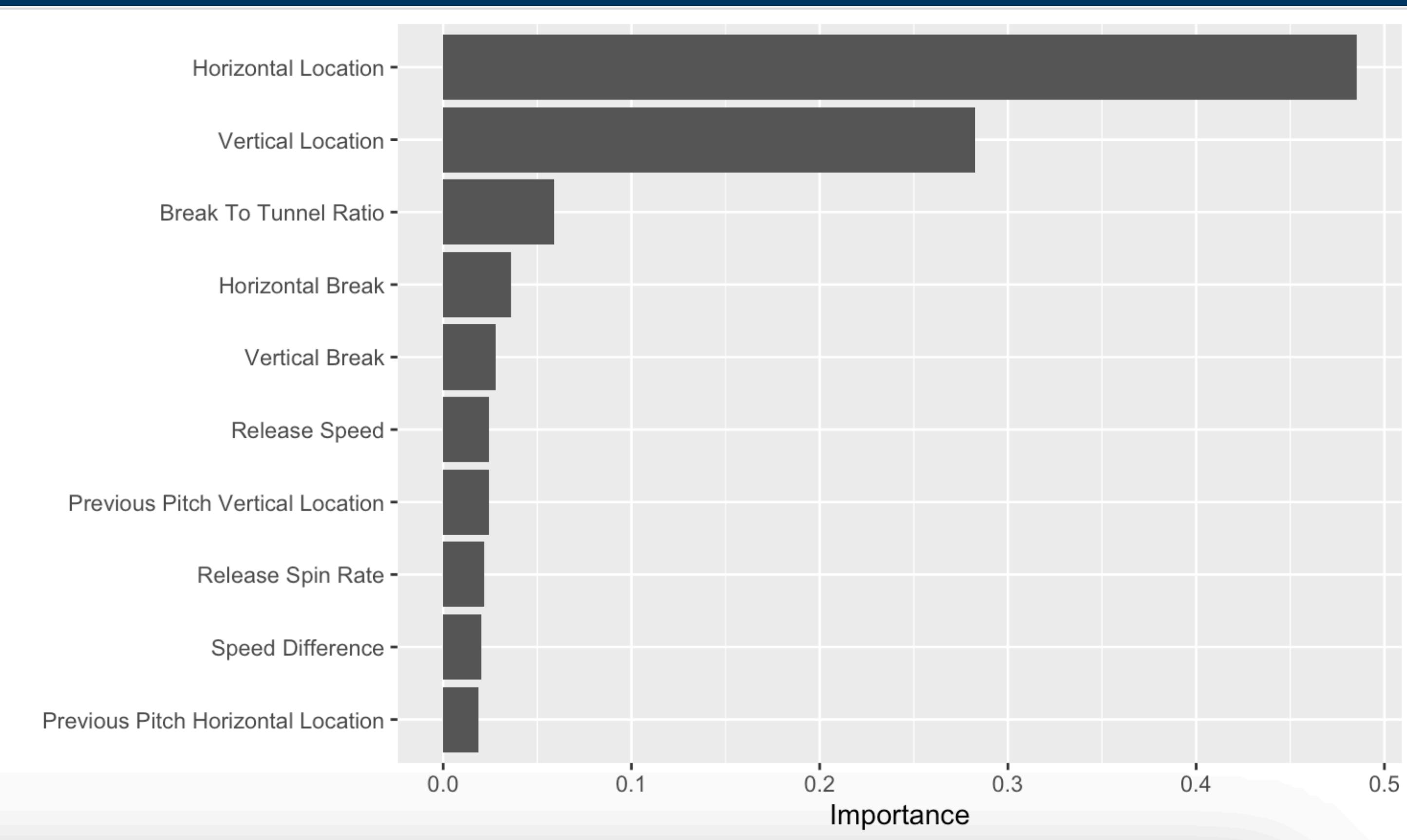


# Four-Seam -> Slider | LHP -> LHH | Chase

**Training Sample: n = 6674 pitches**

**Testing Sample: n = 2862 pitches**

**Testing Accuracy: 69.43%**

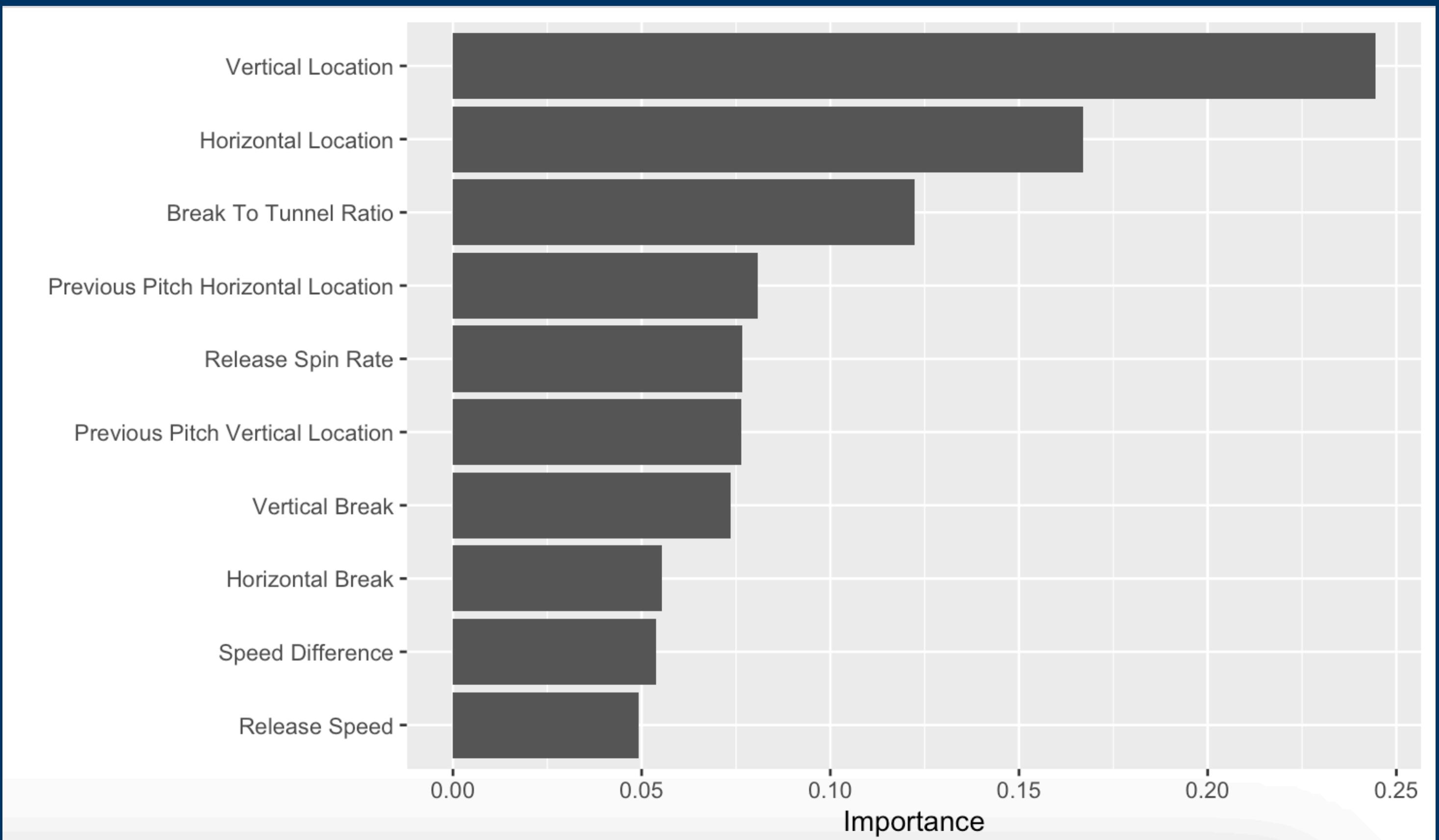


# Four-Seam -> Sweeper | LHP -> LHH | Whiff

**Training Sample: n = 360 pitches**

**Testing Sample: n = 156 pitches**

**Testing Accuracy: 68.59%**

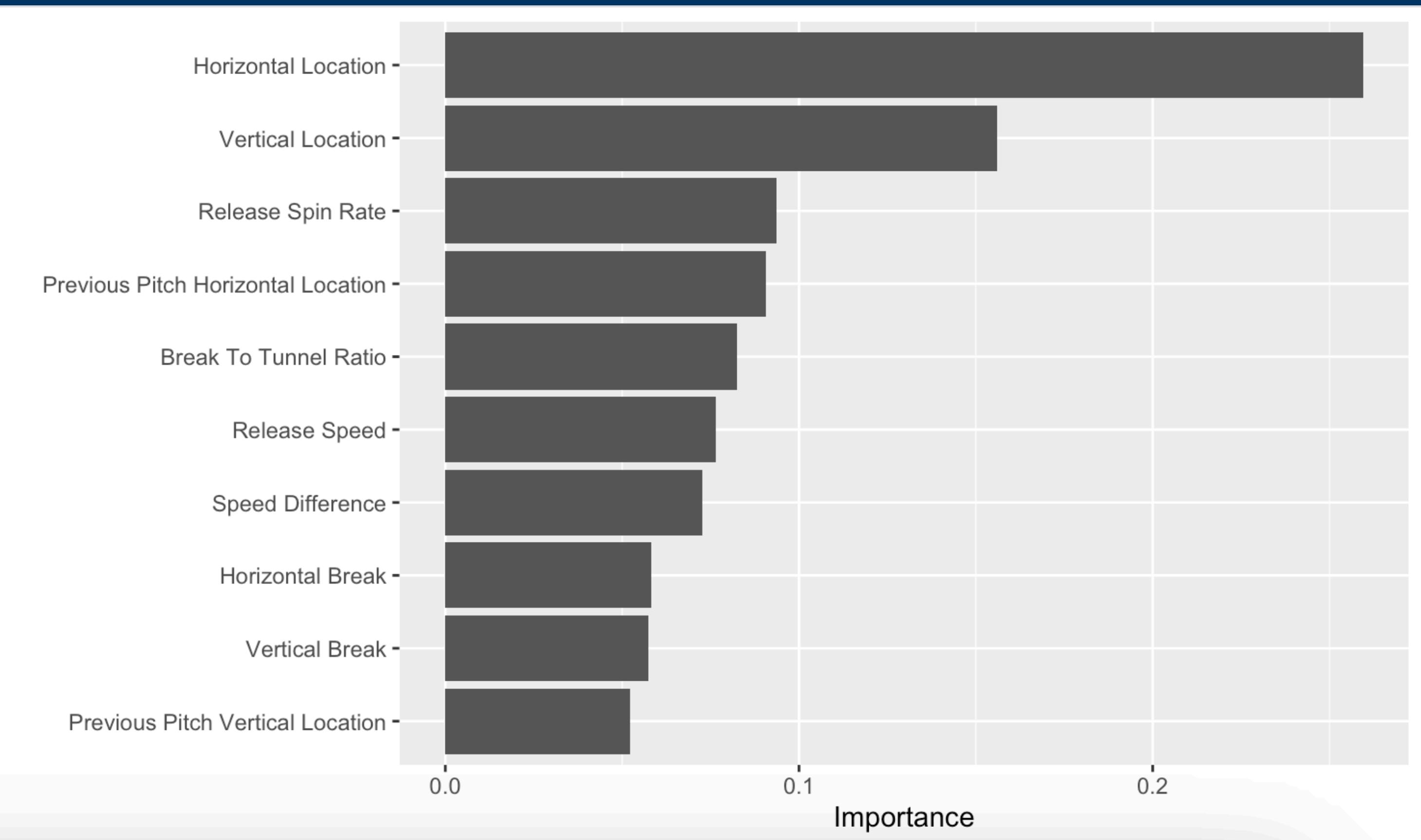


# Four-Seam -> Sweeper | LHP -> LHH | Chase

**Training Sample: n = 452 pitches**

**Testing Sample: n = 196 pitches**

**Testing Accuracy: 74.49%**

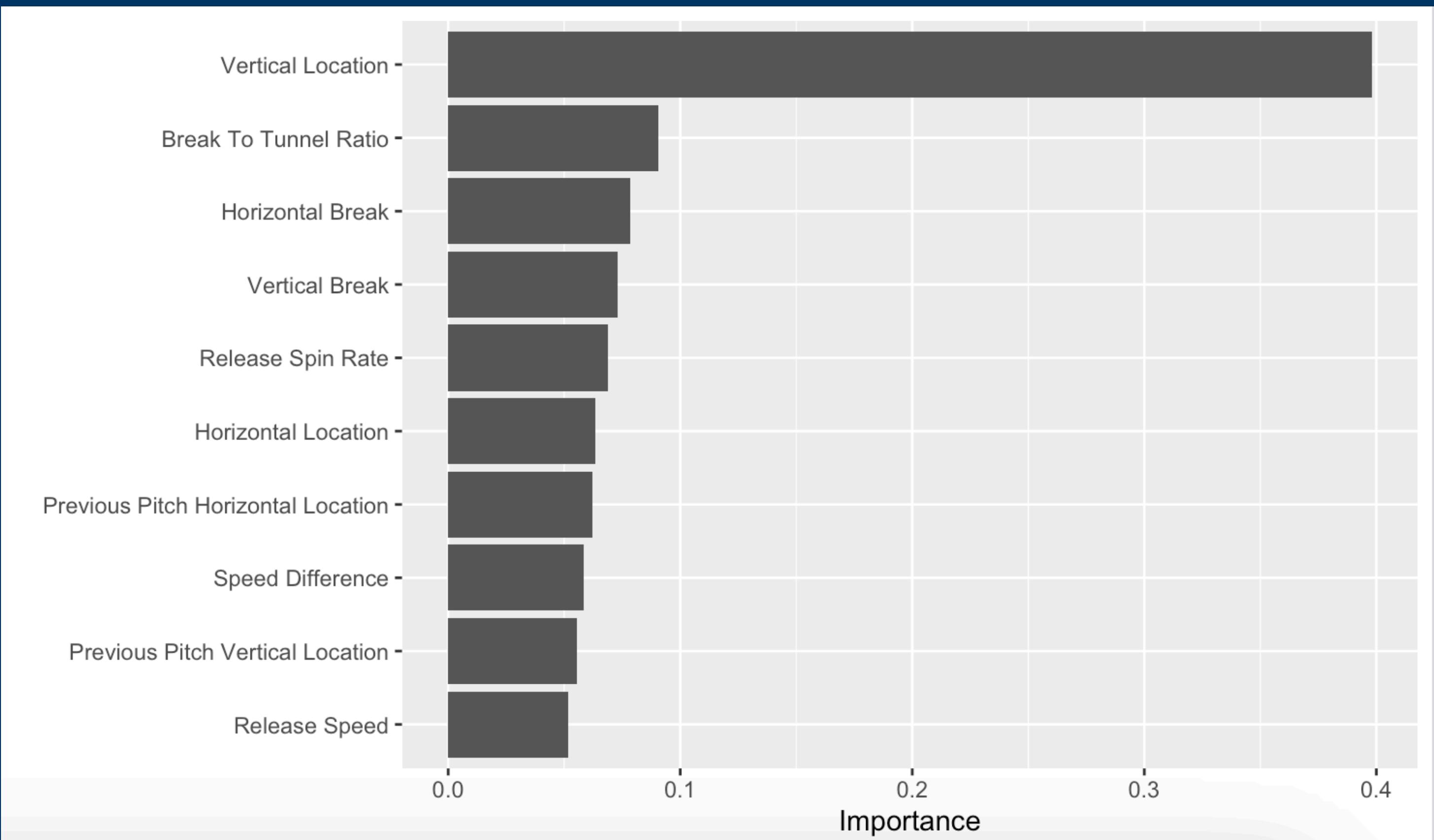


# Sinker -> Changeup | LHP -> LHH | Whiff

**Training Sample: n = 1016 pitches**

**Testing Sample: n = 436 pitches**

**Testing Accuracy: 62.84%**

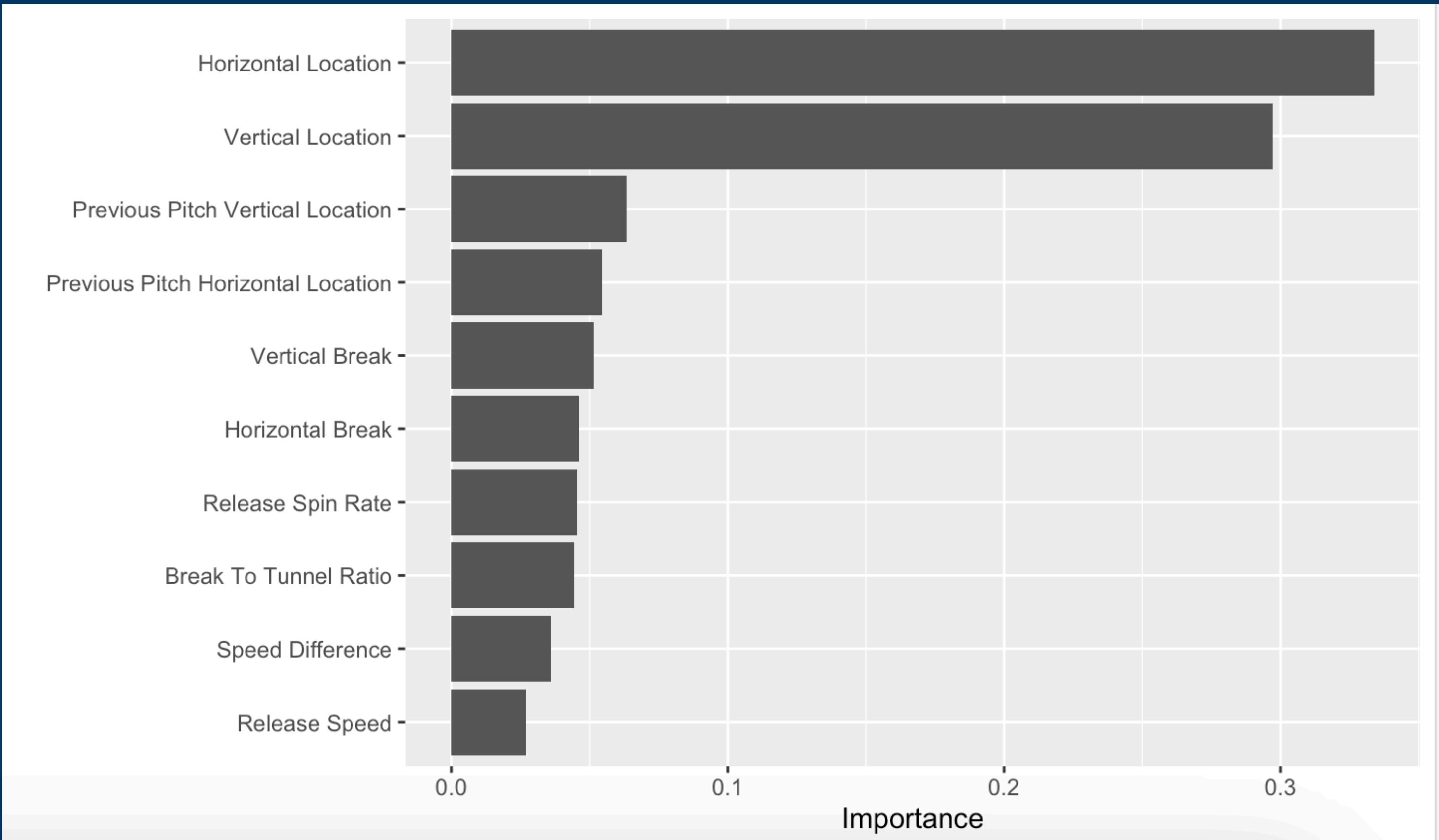


# Sinker -> Changeup | LHP -> LHH | Chase

**Training Sample: n = 1372 pitches**

**Testing Sample: n = 590 pitches**

**Testing Accuracy: 72.54%**

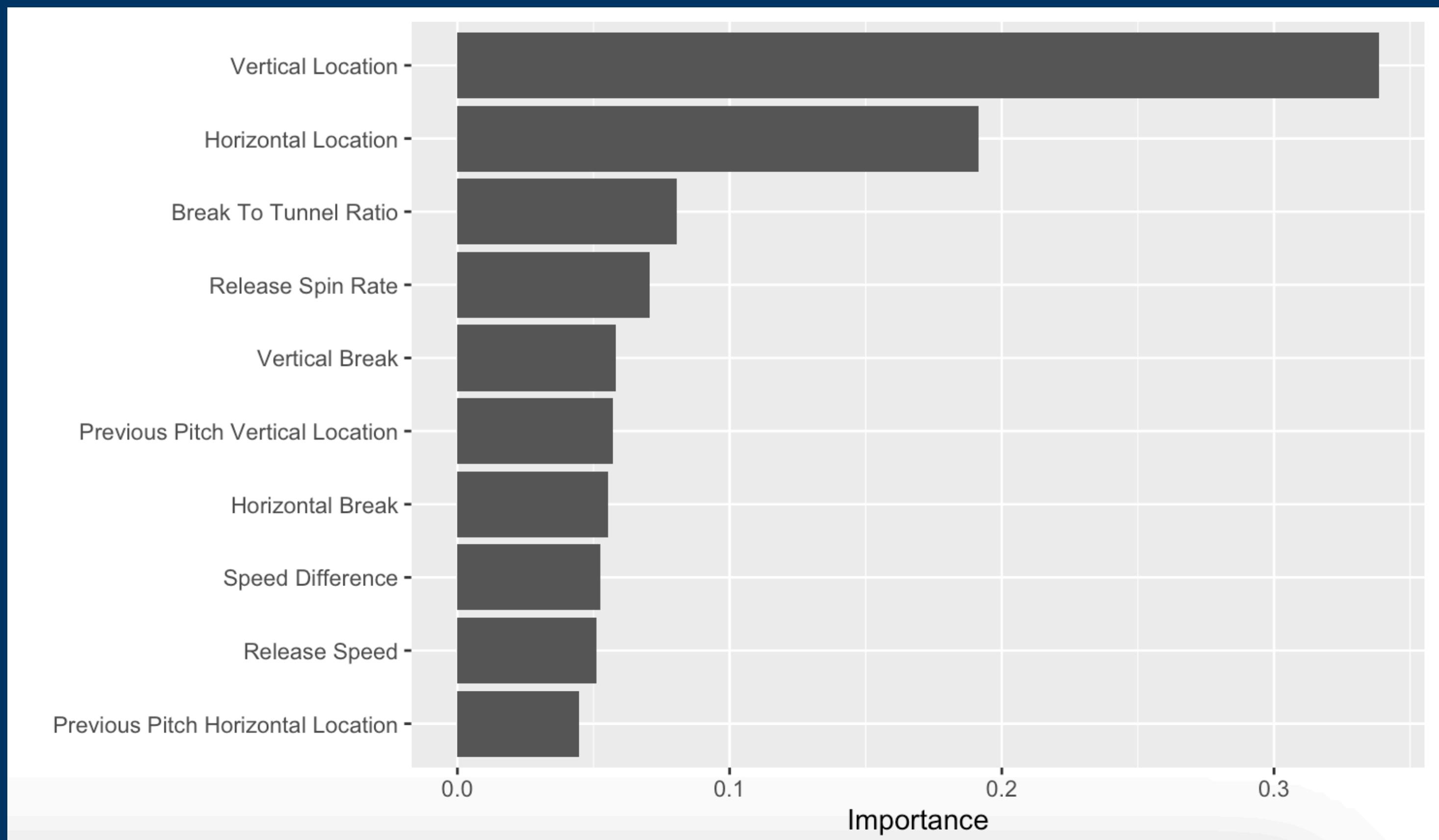


# Sinker -> Curveball | LHP -> LHH | Whiff

**Training Sample: n = 1136 pitches**

**Testing Sample: n = 488 pitches**

**Testing Accuracy: 70.29%**

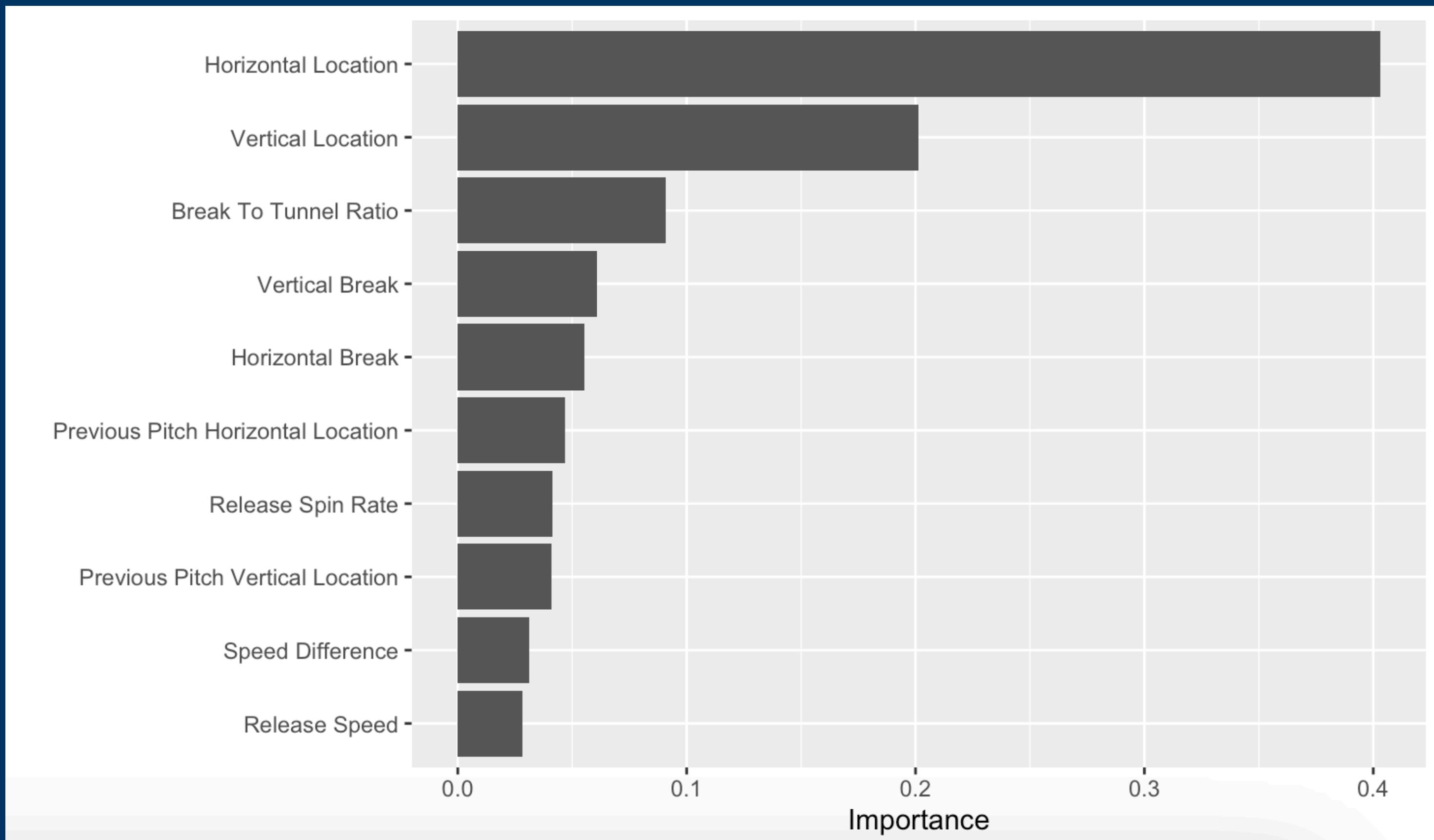


# Sinker -> Curveball | LHP -> LHH | Chase

**Training Sample: n = 1440 pitches**

**Testing Sample: n = 618 pitches**

**Testing Accuracy: 67.48%**

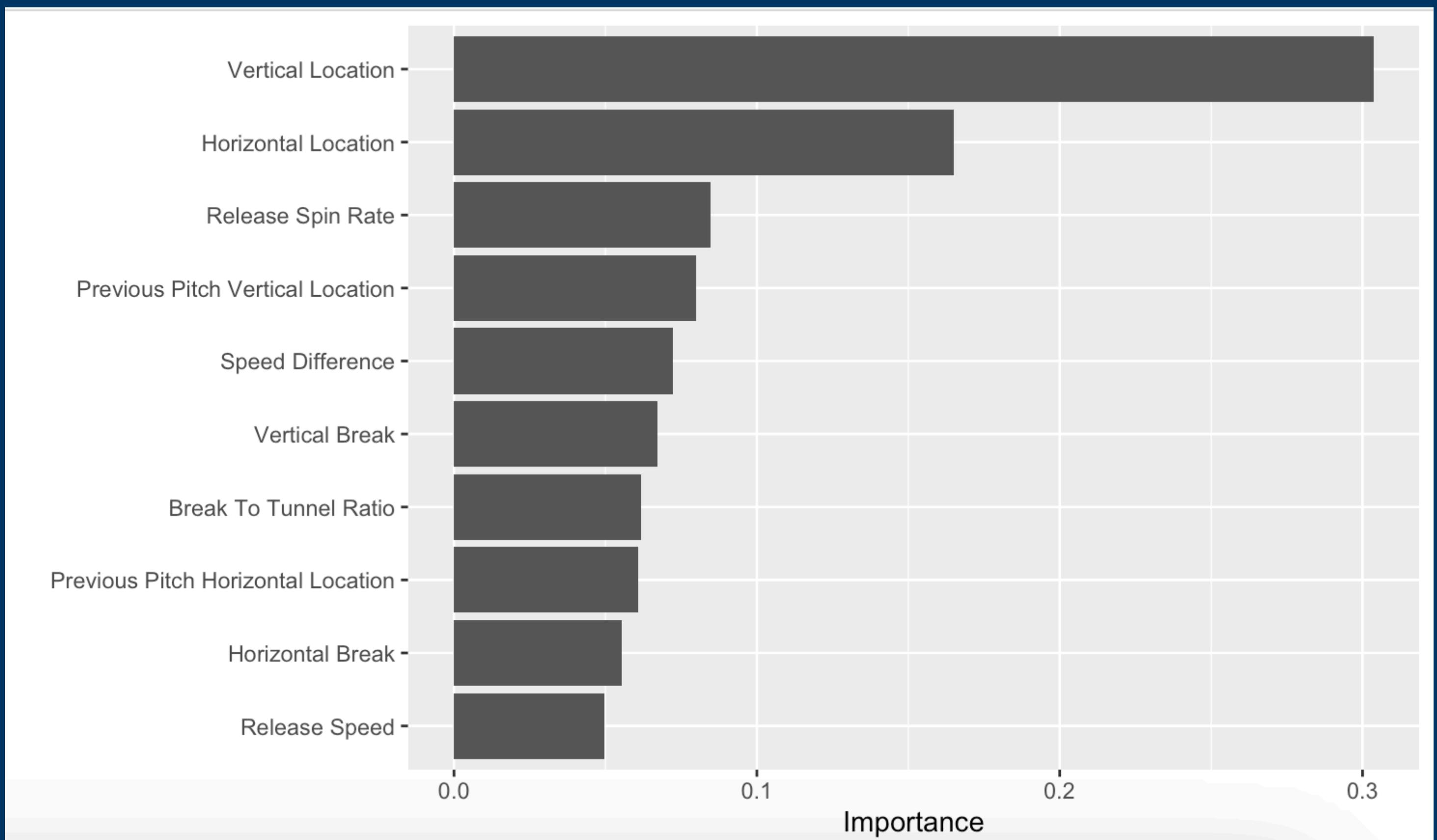


# Sinker -> Knuckle Curve | LHP -> LHH | Whiff

**Training Sample: n = 288 pitches**

**Testing Sample: n = 124 pitches**

**Testing Accuracy: 72.58%**

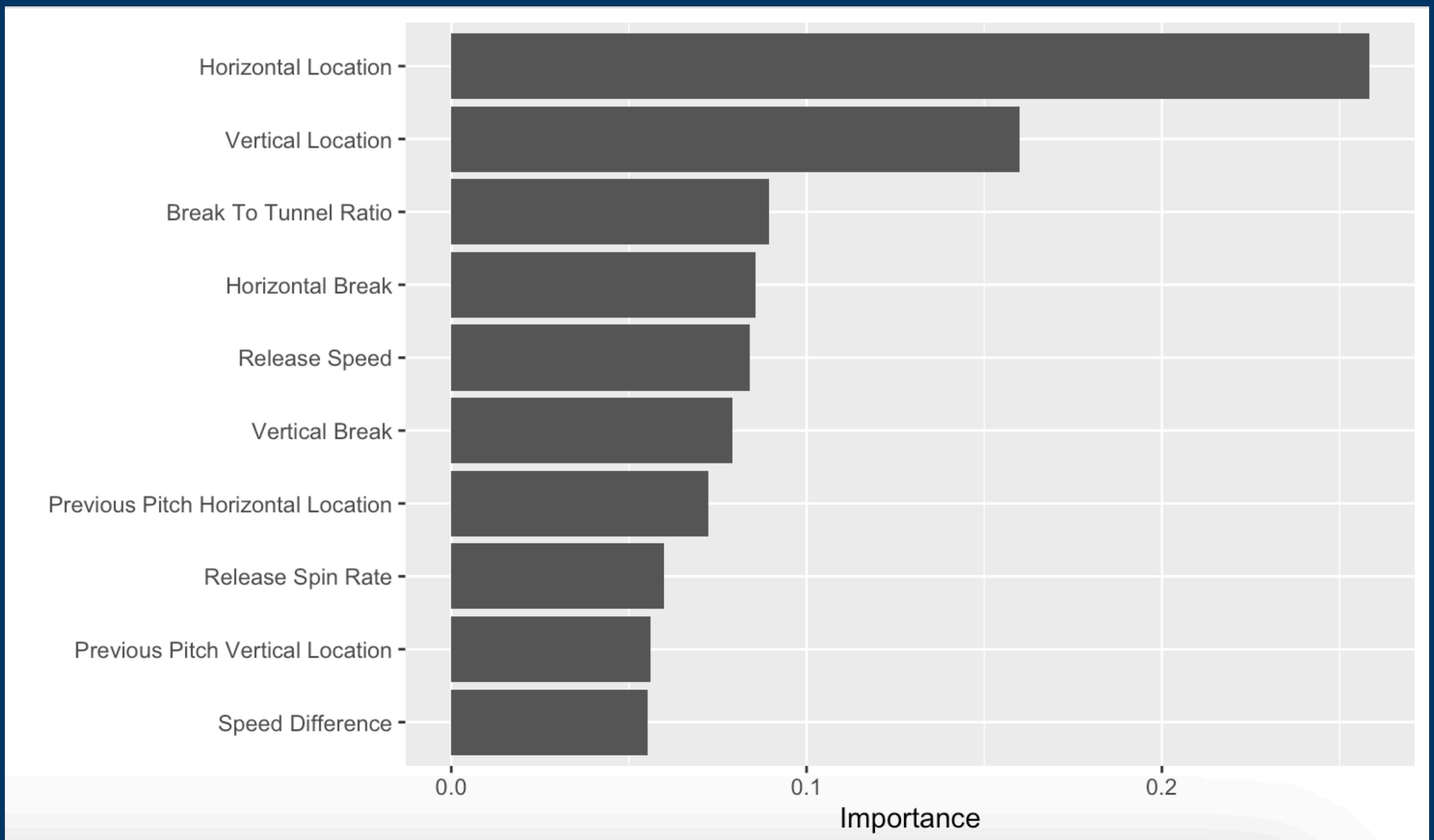


# Sinker -> Knuckle Curve | LHP -> LHH | Chase

**Training Sample: n = 442 pitches**

**Testing Sample: n = 192 pitches**

**Testing Accuracy: 71.35%**

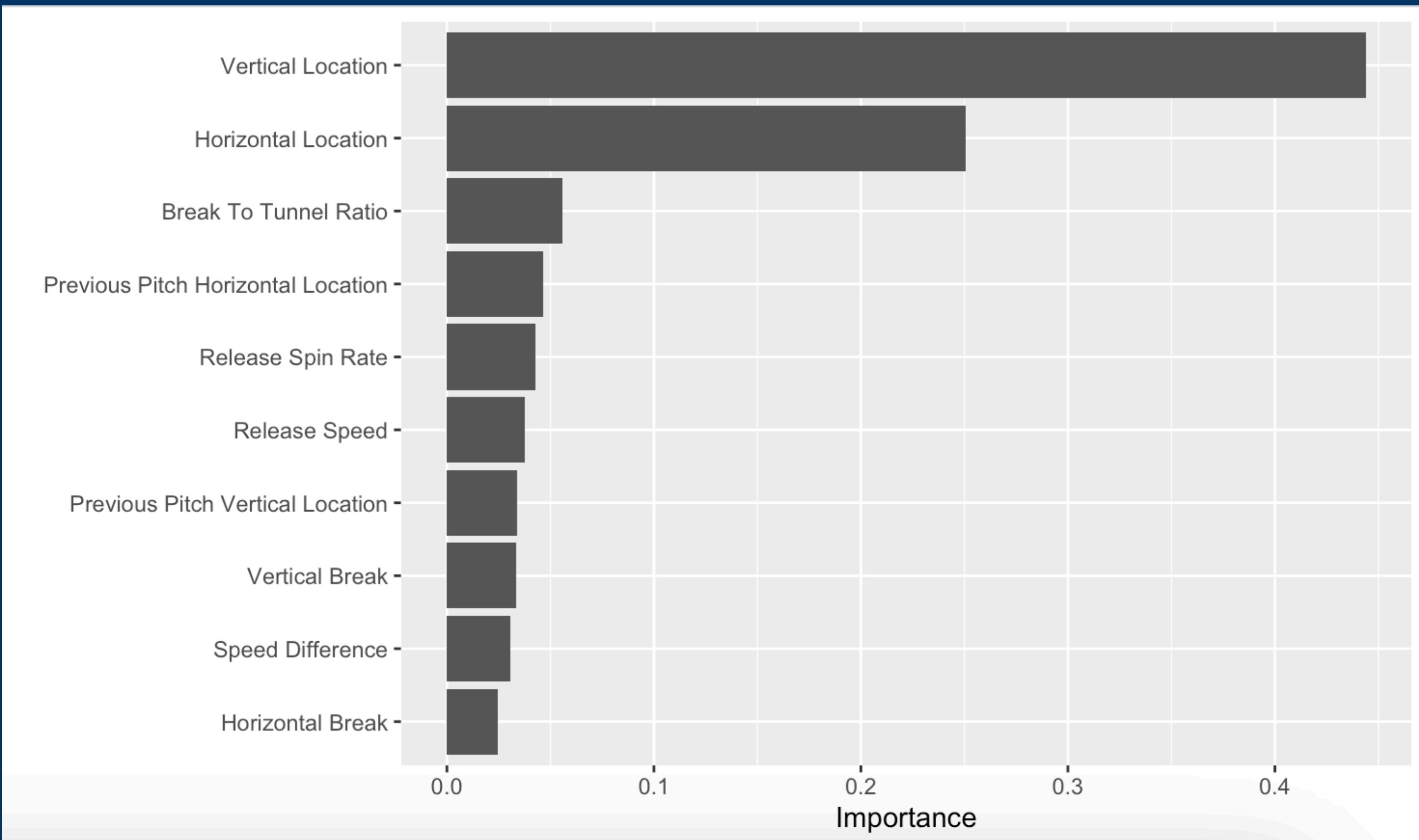


# Sinker -> Slider | LHP -> LHH | Whiff

**Training Sample: n = 3054 pitches**

**Testing Sample: n = 1310 pitches**

**Testing Accuracy: 72.52%**



# Sinker -> Slider | LHP -> LHH | Chase

**Training Sample: n = 3756 pitches**

**Testing Sample: n = 1610 pitches**

**Testing Accuracy: 66.89%**

