

Catch probability EDA

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2025-01-24

```
library(tidyverse)
library(rjson)
library(baseballr)
library(rvest)
```

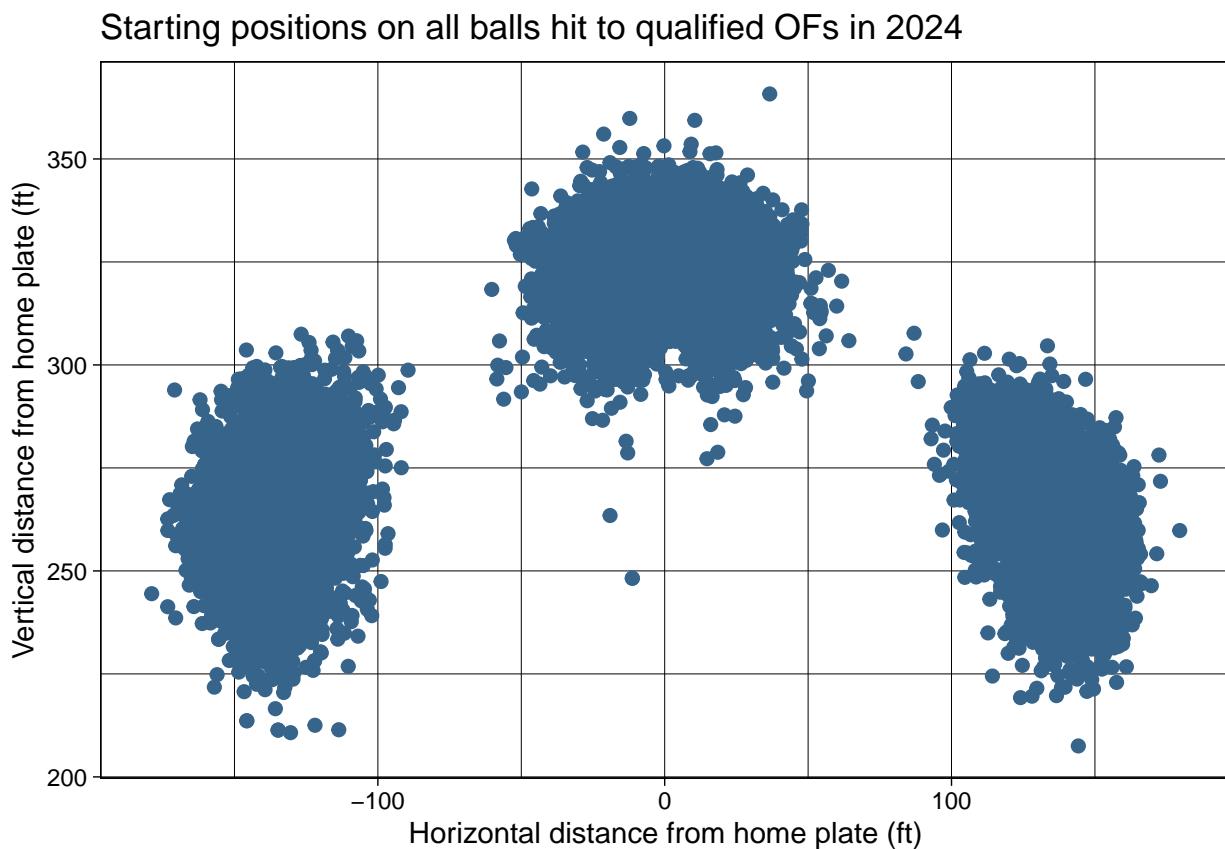
Load in data

```
of_catch_prob_2024 <- read_csv("../data/of_catch_prob_2024.csv") %>%  
  mutate(player = as.factor(player),  
         team = as.factor(team),  
         game_pk = as.factor(game_pk),  
         play_id = as.factor(play_id),  
         player_id = as.factor(player_id),  
         pos = as.factor(pos),  
         route_direction = as.factor(route_direction),  
         ball_section = as.factor(ball_section),  
         stadium = as.factor(stadium))  
  
of_catch_prob_2023 <- read_csv("../data/of_catch_prob_2023.csv") %>%  
  mutate(player = as.factor(player),  
         team = as.factor(team),  
         game_pk = as.factor(game_pk),  
         play_id = as.factor(play_id),  
         player_id = as.factor(player_id),  
         pos = as.factor(pos),  
         route_direction = as.factor(route_direction),  
         ball_section = as.factor(ball_section),  
         stadium = as.factor(stadium))
```

January 2nd

```
jan2_1 <- of_catch_prob_2024 %>%
  ggplot(aes(x = start_pos_x, y = start_pos_y)) +
  geom_point(col = "steelblue4", size = 2, shape = 19) +
  labs(title = "Starting positions on all balls hit to qualified OFs in 2024",
       x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)") +
  theme_linedraw()
```

```
jan2_1
```

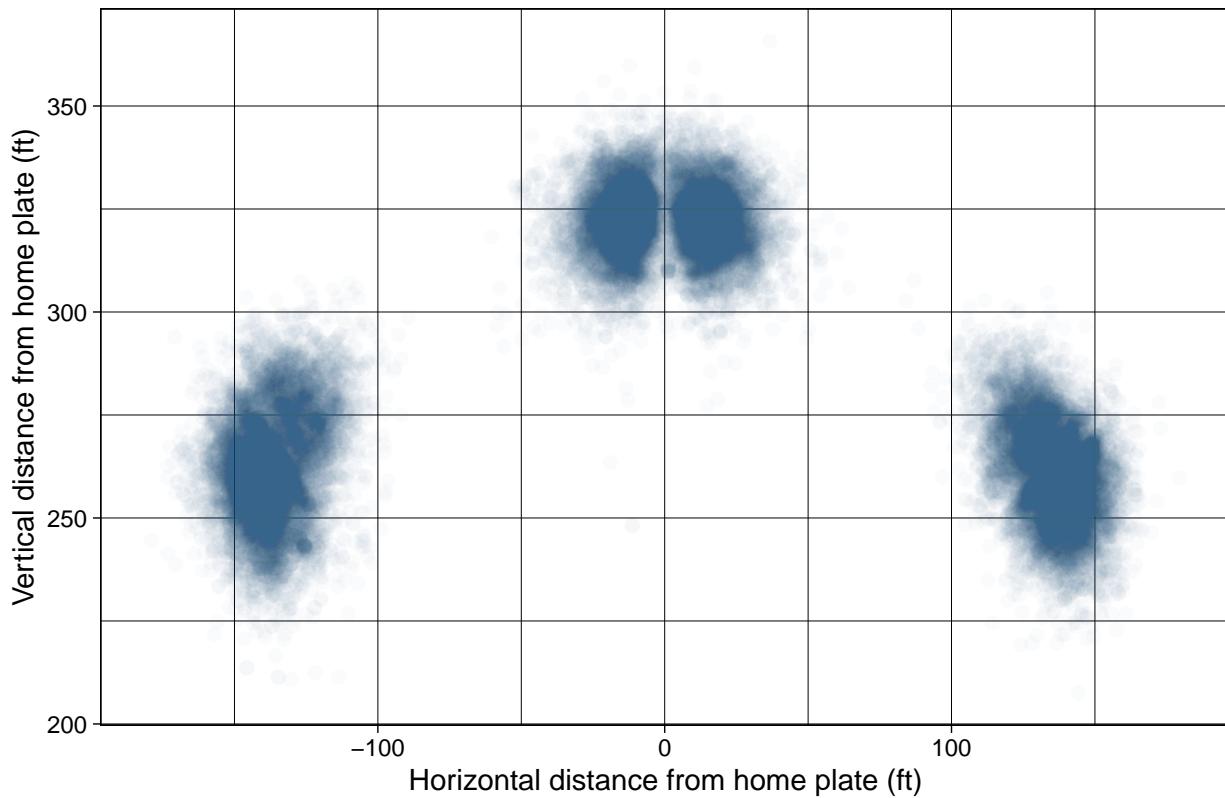


```
ggsave("../figures/jan2_1.png", plot = jan2_1)
```

```
jan2_2 <- of_catch_prob_2024 %>%
  ggplot(aes(x = start_pos_x, y = start_pos_y)) +
  geom_point(col = "steelblue4", size = 2, shape = 19, alpha = 0.025) +
  labs(title = "Starting positions on all balls hit to qualified OFs in 2024",
       x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)") +
  theme_linedraw()
```

```
jan2_2
```

Starting positions on all balls hit to qualified OFs in 2024

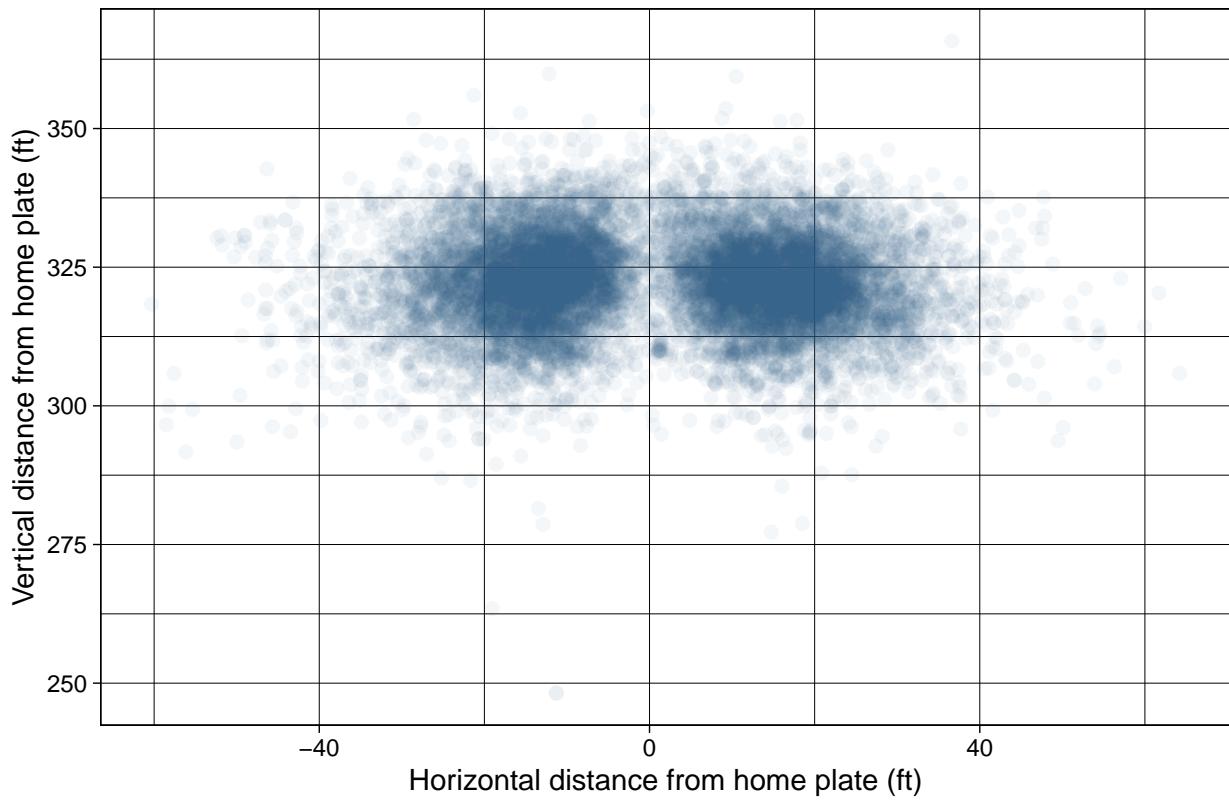


```
ggsave("../figures/jan2_2.png", plot = jan2_2)
```

```
jan2_3 <- of_catch_prob_2024 %>%
  filter(pos == "CF") %>%
  ggplot(aes(x = start_pos_x, y = start_pos_y)) +
  geom_point(col = "steelblue4", size = 2, shape = 19, alpha = 0.05) +
  labs(title = "Starting positions on all balls hit to qualified CFs in 2024",
       x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)") +
  theme_linedraw()
```

```
jan2_3
```

Starting positions on all balls hit to qualified CFs in 2024



```
ggsave("../figures/jan2_3.png", plot = jan2_3)
```

January 4th

```
single_game_oaa <- of_catch_prob_2024 %>%
  group_by(game_pk, player) %>%
  summarize(oaa = sum(out * (1 - catch_rate) - (1 - out) * catch_rate),
            opportunities = n(),
            catches = sum(out),
            stars5_opps = sum(stars == 5),
            stars5_catches = sum(stars == 5 & out == 1),
            stars4_opps = sum(stars == 4),
            stars4_catches = sum(stars == 4 & out == 1),
            stars3_opps = sum(stars == 3),
            stars3_catches = sum(stars == 3 & out == 1),
            stars2_opps = sum(stars == 2),
            stars2_catches = sum(stars == 2 & out == 1),
            stars1_opps = sum(stars == 1),
            stars1_catches = sum(stars == 1 & out == 1),
            stars0_opps = sum(stars == 0),
            stars0_catches = sum(stars == 0 & out == 1),
            .groups = "drop")
```

```
single_game_oaa %>%
  arrange(desc(oaa)) %>%
  head(10)
```

```
## # A tibble: 10 x 17
##   game_pk player      oaa opportunities catches stars5_opps stars5_catches
##   <fct>   <fct>    <dbl>        <int>     <dbl>        <int>        <int>
## 1 745455  Jacob Young  1.84         8          8          2          2
## 2 746097  Pete Crow-Arm~ 1.68         6          6          2          2
## 3 747064  Tyrone Taylor 1.64         6          6          2          2
## 4 745277  Julio Rodríguez 1.61         4          4          1          1
## 5 747121  Fernando Tati~ 1.52         4          4          2          2
## 6 745184  Victor Scott ~ 1.42         4          4          0          0
## 7 744844  Jacob Young    1.39         6          6          1          1
## 8 745716  Tyrone Taylor  1.31         3          3          1          1
## 9 745075  Pete Crow-Arm~ 1.3          2          2          1          1
## 10 745713 Mickey Moniak  1.28        16         14          2          0
## # i 10 more variables: stars4_opps <int>, stars4_catches <int>,
## #   stars3_opps <int>, stars3_catches <int>, stars2_opps <int>,
## #   stars2_catches <int>, stars1_opps <int>, stars1_catches <int>,
## #   stars0_opps <int>, stars0_catches <int>
```

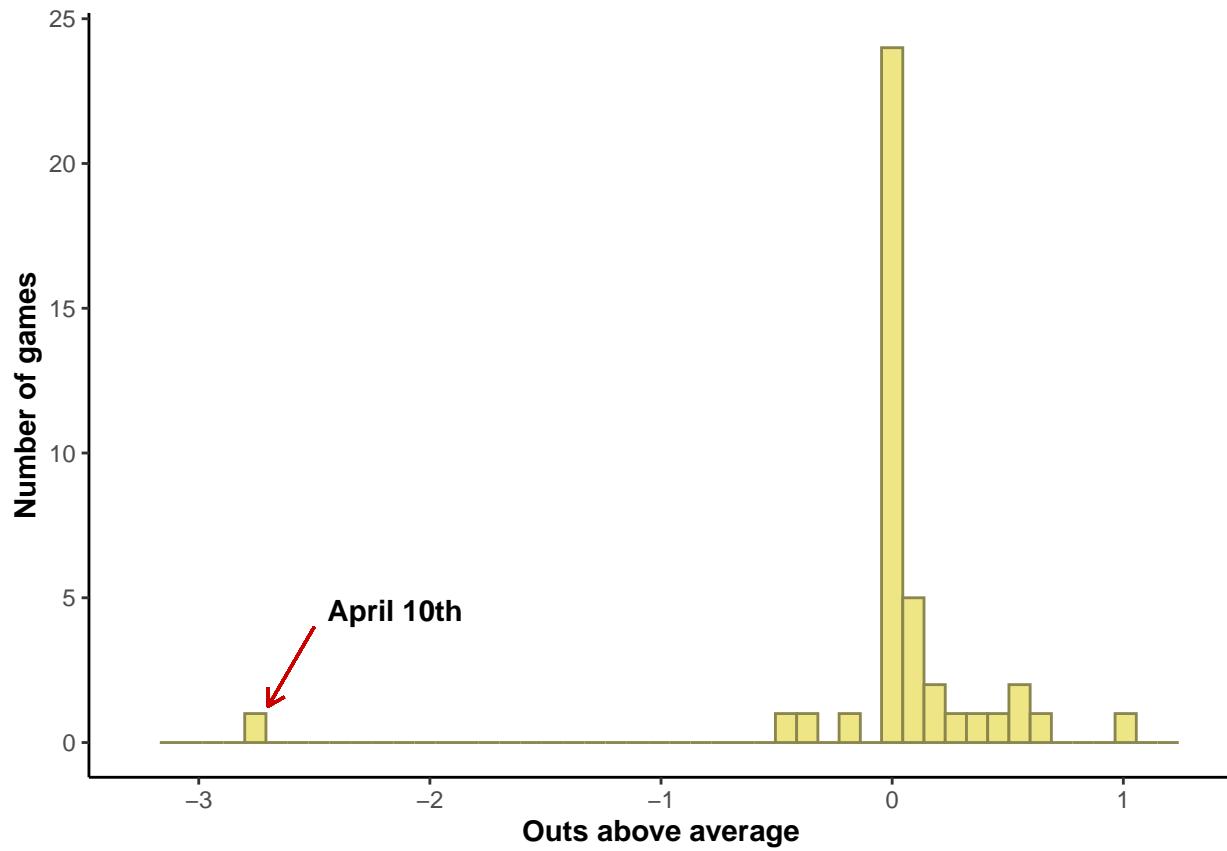
January 6th

```
single_game_oaa %>%
  arrange(oaa) %>%
  head(10)

## # A tibble: 10 x 17
##   game_pk player      oaa opportunities catches stars5_opps stars5_catches
##   <fct>    <fct>    <dbl>        <int>    <dbl>        <int>        <int>
## 1 745196  Victor Scott ~ -2.71         6     3          0          0
## 2 746262  MJ Melendez -2.57         6     2          0          0
## 3 746546  Charlie Black~ -2.34         5     1          1          0
## 4 746931  Tyler O'Neill -2.33         5     2          0          0
## 5 745708  Juan Soto    -2.18         6     2          0          0
## 6 746677  Will Benson  -2.11         6     3          1          0
## 7 745342  Luis Matos  -2.07         7     2          3          0
## 8 746481  Alec Burleson -2.04        10    6          2          0
## 9 746971  Ian Happ     -2.04         4     1          0          0
## 10 745184  Alec Burleson -1.98        2     0          0          0
## # i 10 more variables: stars4_opps <int>, stars4_catches <int>,
## #   stars3_opps <int>, stars3_catches <int>, stars2_opps <int>,
## #   stars2_catches <int>, stars1_opps <int>, stars1_catches <int>,
## #   stars0_opps <int>, stars0_catches <int>

jan6 <- single_game_oaa %>%
  filter(player == "Victor Scott II") %>%
  ggplot() +
  geom_histogram(aes(x = oaa), bins = 50, fill = "khaki2", col = "khaki4") +
  geom_segment(x = -2.5, y = 4, xend = -2.7, yend = 1.25,
               arrow = arrow(length = unit(0.25, "cm")),
               col = "red3") +
  geom_text(x = -2.15, y = 4.55, label = "April 10th", check_overlap = TRUE, fontface = "bold")
  labs(x = "Outs above average", y = "Number of games") +
  xlim(c(-3.25, 1.25)) +
  theme_classic() + theme(axis.title = element_text(face = "bold"))

jan6
```



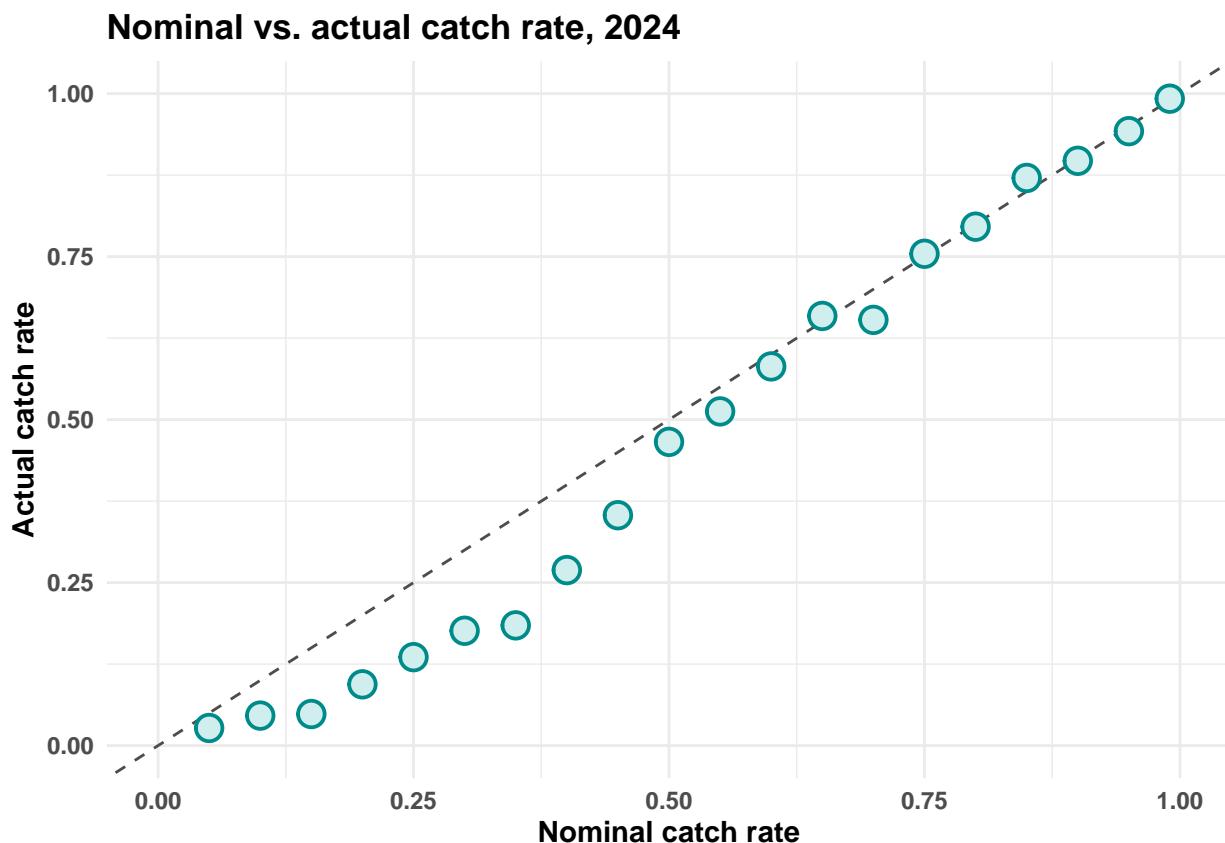
```
ggsave("../figures/jan6.png", plot = jan6, height = 4, width = 6)
```

January 7th

```
calibration_table_2024 <- of_catch_prob_2024 %>%
  group_by(catch_rate) %>%
  summarize(actual_catch_rate = mean(out)) %>%
  rename(nominal_catch_rate = catch_rate)

jan7_1 <- calibration_table_2024 %>%
  ggplot(aes(x = nominal_catch_rate, y = actual_catch_rate)) +
  geom_abline(intercept = 0, slope = 1,
              color = "gray30", linetype = "dashed", linewidth = 0.5) +
  geom_point(pch = 21, col = "cyan4", fill = "lightcyan2",
             size = 4, stroke = 1) +
  theme_minimal() +
  lims(x = c(0,1), y = c(0,1)) +
  labs(x = "Nominal catch rate", y = "Actual catch rate",
       title = "Nominal vs. actual catch rate, 2024") +
  theme(axis.title = element_text(face = "bold"),
        axis.text = element_text(face = "bold"),
        title = element_text(face = "bold"))

jan7_1
```



```
ggsave("../figures/jan7_1.png", plot = jan7_1, height = 4, width = 6)
```

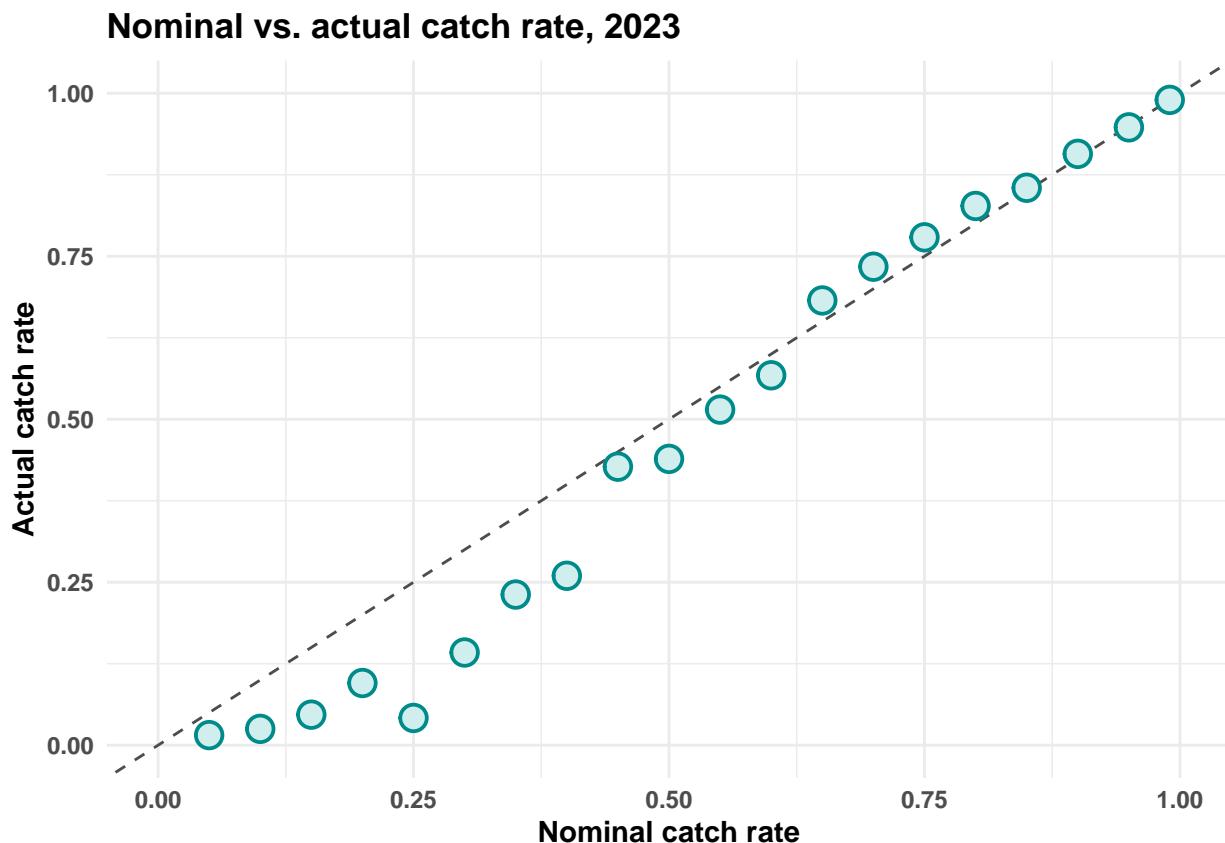
```

calibration_table_2023 <- of_catch_prob_2023 %>%
  group_by(catch_rate) %>%
  summarize(actual_catch_rate = mean(out)) %>%
  rename(nominal_catch_rate = catch_rate)

jan7_2 <- calibration_table_2023 %>%
  ggplot(aes(x = nominal_catch_rate, y = actual_catch_rate)) +
  geom_abline(intercept = 0, slope = 1,
              color = "gray30", linetype = "dashed", linewidth = 0.5) +
  geom_point(pch = 21, col = "cyan4", fill = "lightcyan2",
             size = 4, stroke = 1) +
  theme_minimal() +
  lims(x = c(0,1), y = c(0,1)) +
  labs(x = "Nominal catch rate", y = "Actual catch rate",
       title = "Nominal vs. actual catch rate, 2023") +
  theme(axis.title = element_text(face = "bold"),
        axis.text = element_text(face = "bold"),
        title = element_text(face = "bold"))

```

jan7_2



```
ggsave("../figures/jan7_2.png", plot = jan7_2, height = 4, width = 6)
```

January 8th

```
of_oaa_2024 <- read_csv("../data/of_oaa_2024.csv") %>%
    mutate(player_id = as.factor(player_id))

oaa_rounding_check <- of_catch_prob_2024 %>%
    mutate(catch_rate_upper = pmin(0.999999, catch_rate - 0.02),
          catch_rate_lower = pmin(0.999999, catch_rate + 0.02)) %>%
    group_by(player_id, player) %>%
    summarize(opp = n(),
              oaa_lower = round(sum(out * (1 - catch_rate_lower) - (1 - out) * catch_rate_lower)),
              oaa_estimate = sum(out * (1 - catch_rate) - (1 - out) * catch_rate),
              oaa_upper = round(sum(out * (1 - catch_rate_upper) - (1 - out) * catch_rate_upper)))
    ungroup() %>%
    left_join(of_oaa_2024, by = "player_id") %>%
    select(player_id, name = player, opp,
           oaa_lower, oaa_estimate, oaa_upper, oaa_true = oaa)

oaa_rounding_check %>%
    summarize(any(oaa_true < oaa_lower | oaa_true > oaa_upper))

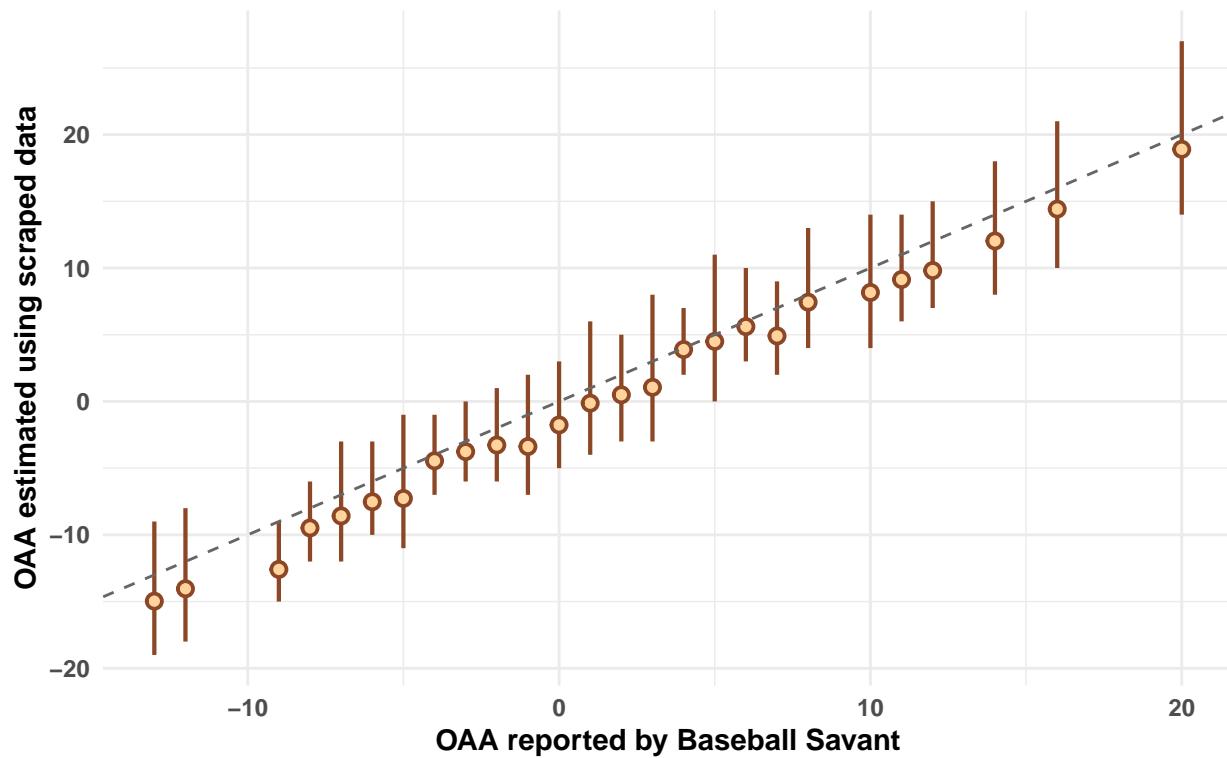
## # A tibble: 1 x 1
##   `any(oaa_true < oaa_lower | oaa_true > oaa_upper)`
##   <lgl>
##   1 FALSE

set.seed(0)
jan8 <- oaa_rounding_check %>%
    filter(opp > 162) %>%
    group_by(oaa_true) %>%
    sample_n(1) %>%
    ggplot(aes(x = oaa_true, y = oaa_estimate)) +
    geom_linerange(aes(ymin = oaa_lower, ymax = oaa_upper), col = "sienna4", linewidth = 0.75) +
    geom_point(size = 2, stroke = 1, pch = 21, fill = "burlywood1", col = "sienna4") +
    geom_abline(intercept = 0, slope = 1, linetype = "dashed", col = "gray40") +
    theme_minimal() +
    labs(x = "OAA reported by Baseball Savant",
         y = "OAA estimated using scraped data",
         title = "Actual vs. estimated OAA for selected players, 2024",
         subtitle = "Lower and upper bounds computed by changing each catch rate by +/-0.02") +
    theme(axis.title = element_text(face = "bold"),
          axis.text = element_text(face = "bold"),
          title = element_text(face = "bold"))

jan8
```

Actual vs. estimated OAA for selected players, 2024

Lower and upper bounds computed by changing each catch rate by +/-0.02

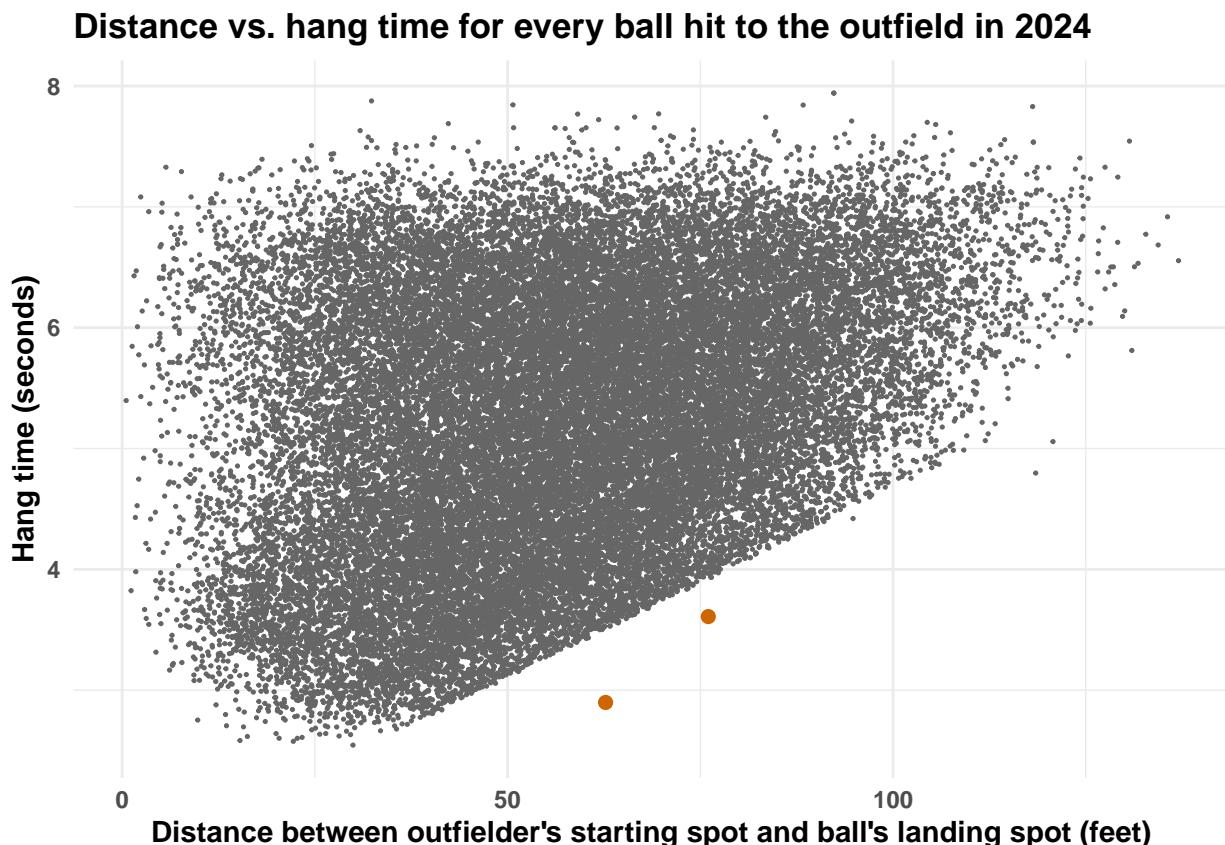


```
ggsave("../figures/jan8.png", plot = jan8, height = 4, width = 6)
```

January 9th

```
jan9 <- of_catch_prob_2024 %>%
  mutate(highlight = (hang_time < 3 & distance > 50) | (hang_time < 3.8 & distance > 75)) %>%
  ggplot(aes(x = distance, y = hang_time, col = highlight, size = highlight)) +
  geom_point() +
  scale_colour_manual(values = c("gray40", "darkorange3")) +
  scale_size_manual(values = c(0.25, 2)) +
  theme_minimal() +
  theme(legend.position = "none",
        axis.title = element_text(face = "bold"),
        axis.text = element_text(face = "bold"),
        title = element_text(face = "bold")) +
  labs(x = "Distance between outfielder's starting spot and ball's landing spot (feet)",
       y = "Hang time (seconds)",
       title = "Distance vs. hang time for every ball hit to the outfield in 2024")
```

jan9



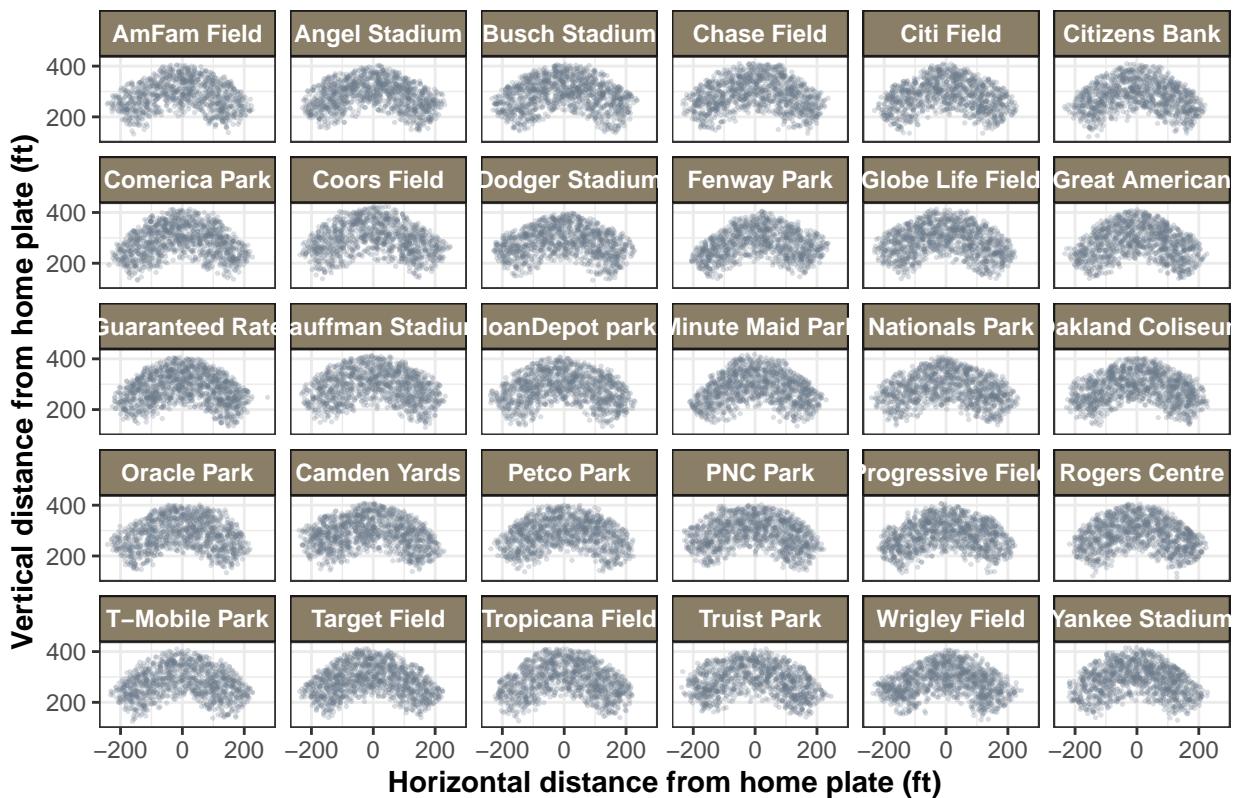
```
ggsave("../figures/jan9.png", plot = jan9, height = 4, width = 6)
```

January 17th

```
jan17_1 <- of_catch_prob_2024 %>%
  mutate(stadium = fct_recode(stadium,
    "AmFam Field" = "American Family Field",
    "Guaranteed Rate" = "Guaranteed Rate Field",
    "Camden Yards" = "Oriole Park at Camden Yards",
    "Great American" = "Great American Ball Park",
    "Citizens Bank" = "Citizens Bank Park"
  )) %>%
  ggplot(aes(x = landing_pos_x, y = landing_pos_y)) +
  geom_point(size = 0.25, alpha = 0.25, col = "slategray4") +
  facet_wrap(~stadium, scales = "fixed") +
  theme_bw() +
  labs(x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)",
       title = "Landing positions of fly balls by stadium, 2024") +
  theme(axis.title = element_text(face = "bold"),
        title = element_text(face = "bold"),
        plot.subtitle = element_text(face = "italic"),
        strip.background = element_rect(fill = "wheat4", color = "gray10"),
        strip.text = element_text(face = "bold", color = "white")) +
  scale_x_continuous(breaks = c(-200, 0, 200)) +
  scale_y_continuous(breaks = c(200, 400))
```

```
jan17_1
```

Landing positions of fly balls by stadium, 2024

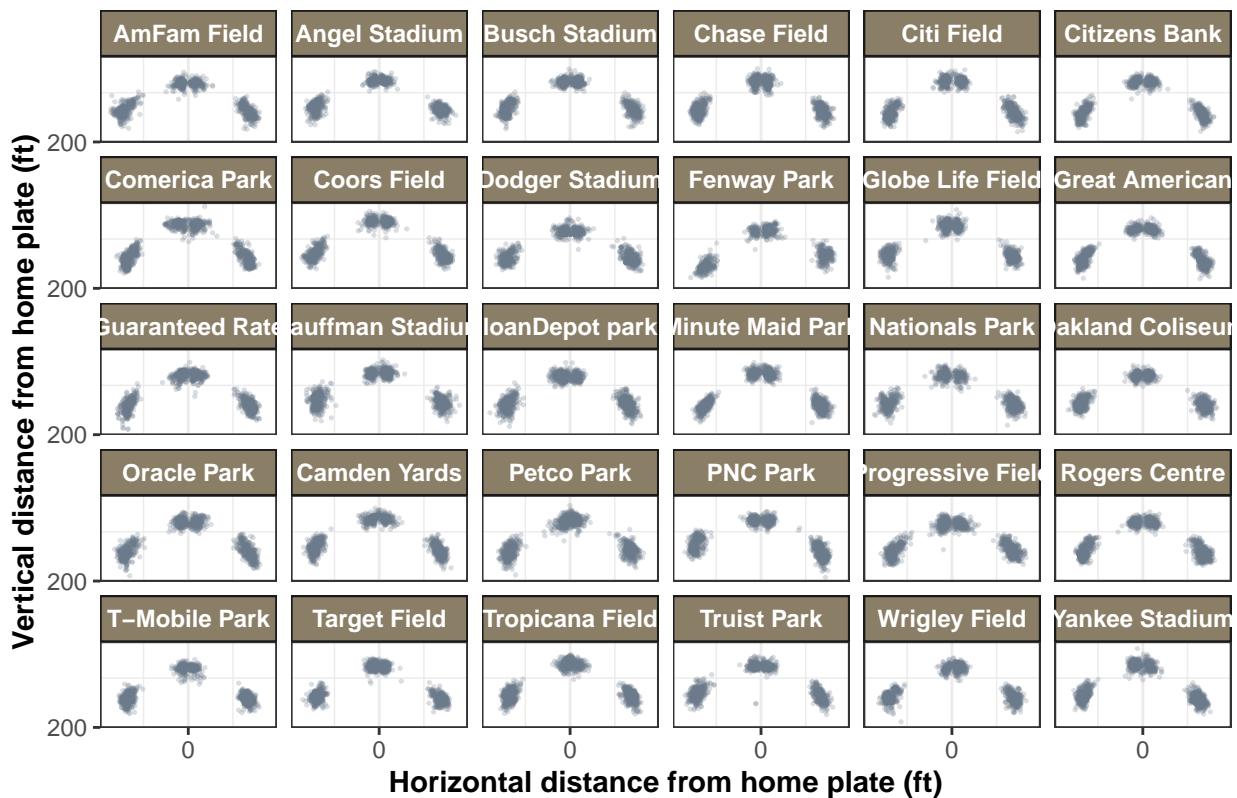


```
ggsave("../figures/jan17_1.png", plot = jan17_1, height = 6, width = 8)
```

```
jan17_2 <- of_catch_prob_2024 %>%
  mutate(stadium = fct_recode(stadium,
    "AmFam Field" = "American Family Field",
    "Guaranteed Rate" = "Guaranteed Rate Field",
    "Camden Yards" = "Oriole Park at Camden Yards",
    "Great American" = "Great American Ball Park",
    "Citizens Bank" = "Citizens Bank Park"
  )) %>%
  ggplot(aes(x = start_pos_x, y = start_pos_y)) +
  geom_point(size = 0.25, alpha = 0.25, col = "slategray4") +
  facet_wrap(~stadium, scales = "fixed") +
  theme_bw() +
  labs(x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)",
       title = "Starting positions of outfielders by stadium, 2024") +
  theme(axis.title = element_text(face = "bold"),
        title = element_text(face = "bold"),
        plot.subtitle = element_text(face = "italic"),
        strip.background = element_rect(fill = "wheat4", color = "gray10"),
        strip.text = element_text(face = "bold", color = "white")) +
  scale_x_continuous(breaks = c(-200, 0, 200)) +
  scale_y_continuous(breaks = c(200, 400))
```

```
jan17_2
```

Starting positions of outfielders by stadium, 2024



```
ggsave("../figures/jan17_2.png", plot = jan17_2, height = 6, width = 8)
```

January 18th

```
stadium_dims <- of_catch_prob_2024 %>%
  distinct(stadium, .keep_all = TRUE) %>%
  select(stadium, starts_with("wall_height"), starts_with("dist_"))

pca <- prcomp(stadium_dims %>% select(-stadium), center = TRUE, scale = TRUE)

pca

## Standard deviations (1, ..., p=8):
## [1] 1.6133522 1.2413816 1.0530766 1.0052921 0.9336312 0.7679162 0.4447214
## [8] 0.2781085
##
## Rotation (n x k) = (8 x 8):
##          PC1      PC2      PC3      PC4      PC5
## wall_height_lf -0.52563253 -0.16252938  0.01261898 -0.2306161  0.31539308
## wall_height_cf -0.21369818 -0.46724246  0.45415128 -0.2028672 -0.24556732
## wall_height_rf  0.28717525  0.28246940  0.35896996  0.1042763  0.67175299
## dist_lf         0.48507818 -0.28088096  0.01297260 -0.3375695  0.32213101
## dist_lc         0.46879974  0.06248463  0.25797717  0.2568213 -0.47910240
## dist_cf         -0.01629932 -0.35294451 -0.50995086  0.6384369  0.17928122
## dist_rc         0.04235743 -0.56952669  0.41248946  0.3622816  0.14825164
## dist_rf         0.37207533 -0.37914483 -0.40964618 -0.4195565 -0.03929392
##          PC6      PC7      PC8
## wall_height_lf  0.00962424  0.69004304 -0.26120262
## wall_height_cf  0.59259431 -0.26984609 -0.06573315
## wall_height_rf  0.43090688  0.08794958  0.23095562
## dist_lf         -0.19532159 -0.19154215 -0.62695794
## dist_lc         0.14069505  0.57057383 -0.26253451
## dist_cf         0.35684595 -0.04124903 -0.21524573
## dist_rc         -0.49849021  0.06888202  0.31182355
## dist_rf         0.17111831  0.27312902  0.51821479

summary(pca)

## Importance of components:
##          PC1      PC2      PC3      PC4      PC5      PC6      PC7
## Standard deviation 1.6134 1.2414 1.0531 1.0053 0.9336 0.76792 0.44472
## Proportion of Variance 0.3254 0.1926 0.1386 0.1263 0.1090 0.07371 0.02472
## Cumulative Proportion 0.3254 0.5180 0.6566 0.7829 0.8919 0.96561 0.99033
##          PC8
## Standard deviation 0.27811
## Proportion of Variance 0.00967
## Cumulative Proportion 1.00000

set.seed(18)

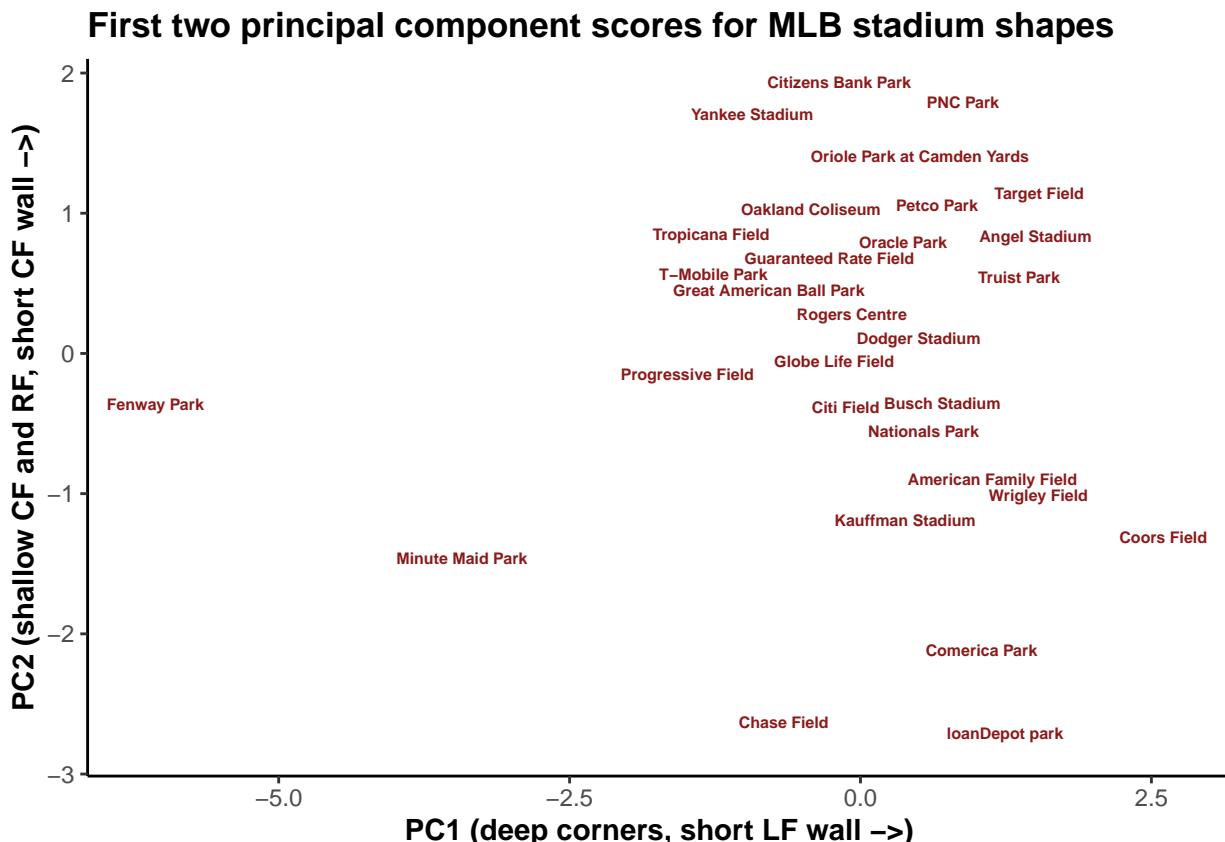
jan18 <- tibble(stadium = stadium_dims$stadium,
  pc1 = pca$x[,1], pc2 = pca$x[,2], pc3 = pca$x[,3]) %>%
  ggplot(aes(x = pc1, y = pc2)) +
```

```

ggrepel::geom_text_repel(aes(label = stadium), fontface = "bold", col = "firebrick4",
                         min.segment.length = 1,
                         label.padding = 0.0, box.padding = 0.05, point.padding = 0,
                         size = 2, max.overlaps = 30) +
  theme_classic() +
  labs(title = "First two principal component scores for MLB stadium shapes",
       x = "PC1 (deep corners, short LF wall ->)",
       y = "PC2 (shallow CF and RF, short CF wall ->)") +
  theme(axis.title = element_text(face = "bold"),
        title = element_text(face = "bold"))

```

jan18



```
ggsave("../figures/jan18.png", plot = jan18, height = 4, width = 6)
```

January 21st

```
set.seed(121)

play_ids <- ofCatchProb_2024 %>%
  filter(distance > 60) %>%
  filter(route_angle %% 60 > 20) %>%
  group_by(route_direction) %>% sample_n(1) %>% pull(play_id)

jan21 <- ofCatchProb_2024 %>%
  filter(play_id %in% play_ids) %>%
  mutate(route_angle = paste0("route angle = ", round(route_angle), " degrees")) %>%
  ggplot() +
  geom_segment(aes(x = start_pos_x, y = start_pos_y,
                    xend = landing_pos_x, yend = landing_pos_y),
               arrow = arrow(length = unit(0.1, "inches"))) +
  geom_segment(aes(x = start_pos_x, y = start_pos_y,
                    xend = 0, yend = 0)) +
  geom_abline(aes(intercept = (start_pos_x^2 + start_pos_y^2) / start_pos_y,
                  slope = -start_pos_x/start_pos_y), color = "gray40", linetype = "dotted") +
  geom_point(x = 0, y = 0, pch = 15) +
  geom_point(aes(x = start_pos_x, y = start_pos_y), col = "steelblue4", size = 3, pch = 17) +
  geom_point(aes(x = landing_pos_x, y = landing_pos_y), color = "firebrick3", size = 3) +
  facet_wrap(~route_angle) +
  labs(x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)") +
  xlim(c(-200, 200)) + ylim(c(0, 400)) + coord_fixed() +
  theme_bw()

ggsave("../figures/jan21.png", plot = jan21, height = 4, width = 6)
```

January 22nd

```
of_catch_prob_2024 %>%
  count(back_bs = as.factor(of_catch_prob_2024$back),
    back_mine = as.factor(ifelse(
      of_catch_prob_2024$route_direction == "back_middle",
      1, 0)))
```

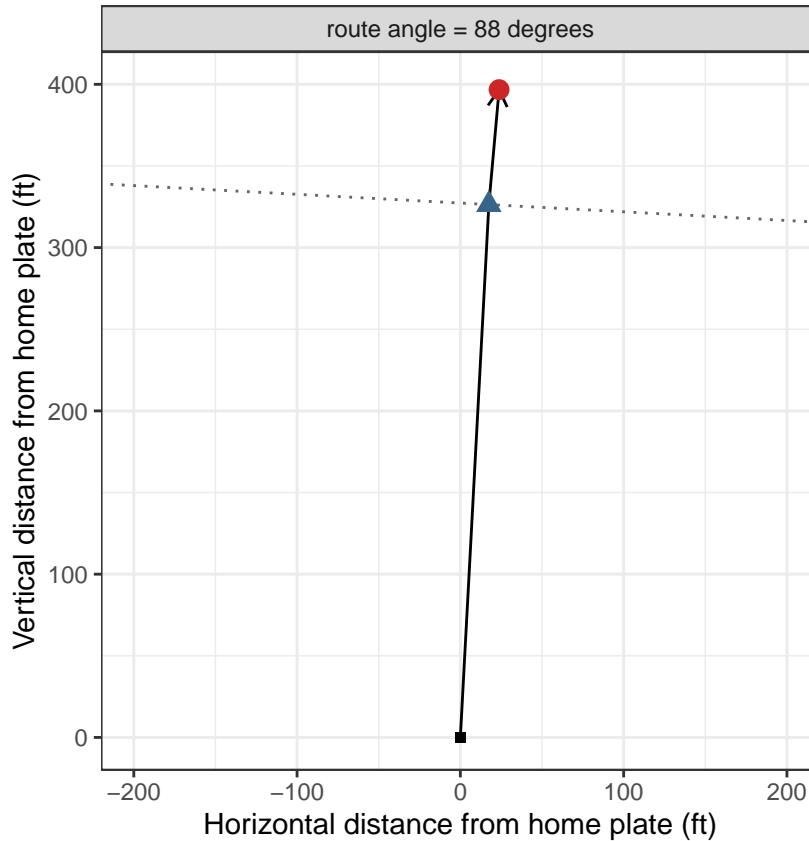


```
## # A tibble: 4 x 3
##   back_bs back_mine     n
##   <fct>    <fct>   <int>
## 1 0         0        28152
## 2 0         1        1589
## 3 1         0        1998
## 4 1         1        3080
```

January 23rd

```
jan23 <- of_catch_prob_2024 %>%
  filter(play_id == "925eb5a8-b6ff-42ca-ab2e-3ac950c76259") %>%
  mutate(route_angle = paste0("route angle = ", round(route_angle), " degrees")) %>%
  ggplot() +
  geom_segment(aes(x = start_pos_x, y = start_pos_y,
                    xend = landing_pos_x, yend = landing_pos_y),
               arrow = arrow(length = unit(0.1, "inches"))) +
  geom_segment(aes(x = start_pos_x, y = start_pos_y,
                    xend = 0, yend = 0)) +
  geom_abline(aes(intercept = (start_pos_x^2 + start_pos_y^2) / start_pos_y,
                  slope = -start_pos_x/start_pos_y), color = "gray40", linetype = "dotted") +
  geom_point(x = 0, y = 0, pch = 15) +
  geom_point(aes(x = start_pos_x, y = start_pos_y), col = "steelblue4", size = 3, pch = 17) +
  geom_point(aes(x = landing_pos_x, y = landing_pos_y), color = "firebrick3", size = 3) +
  facet_wrap(~route_angle) +
  labs(x = "Horizontal distance from home plate (ft)",
       y = "Vertical distance from home plate (ft)") +
  xlim(c(-200, 200)) + ylim(c(0, 400)) + coord_fixed() +
  theme_bw()
```

jan23



```
ggsave("../figures/jan23.png", plot = jan23, height = 4, width = 6)
```

January 24th

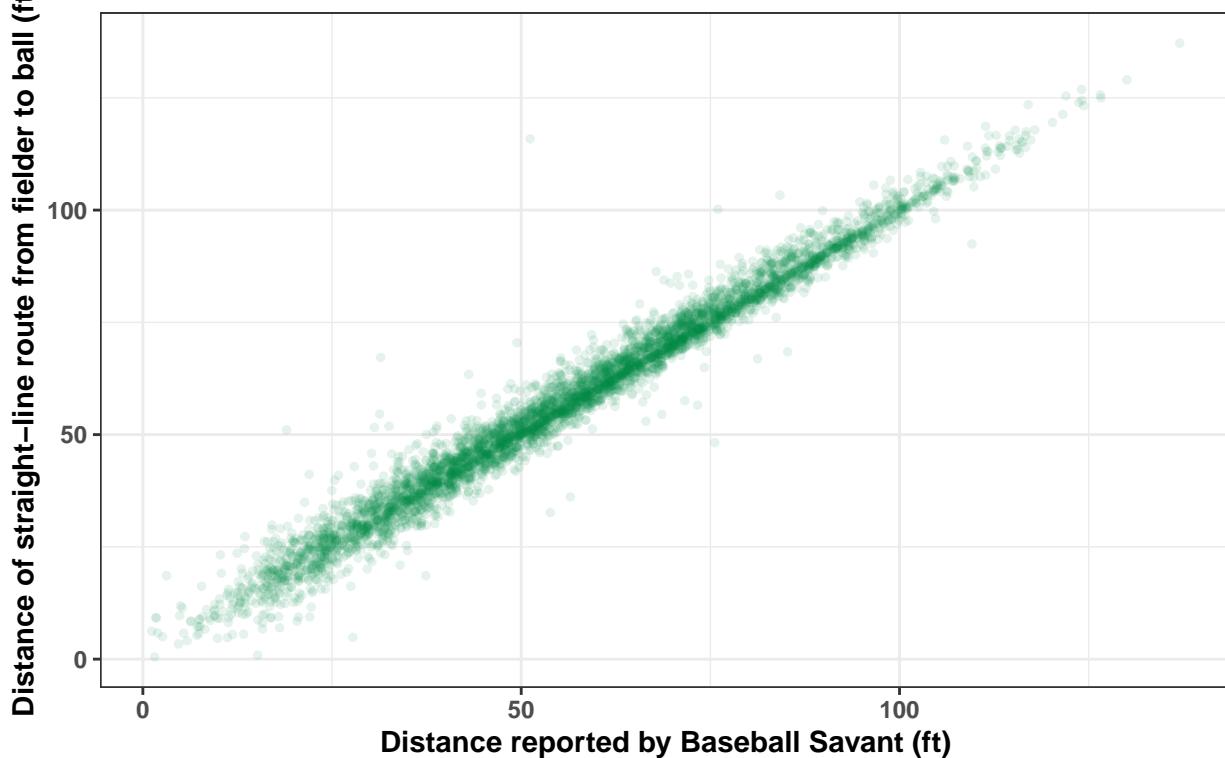
```
set.seed(124)

jan24 <- of_catch_prob_2024 %>%
  sample_n(5000) %>%
  mutate(route_distance = sqrt(
    (landing_pos_x - start_pos_x)^2 + (landing_pos_y - start_pos_y)^2)
  ) %>%
  ggplot(aes(x = distance, y = route_distance)) +
  geom_point(size = 1, alpha = 0.1, color = "springgreen4") +
  labs(x = "Distance reported by Baseball Savant (ft)",
       y = "Distance of straight-line route from fielder to ball (ft)",
       title = "Statcast distances vs. straight-line route distances",
       subtitle = "5,000 randomly sampled fly balls from the 2024 season") +
  theme_bw() +
  theme(axis.title = element_text(face = "bold"),
        axis.text = element_text(face = "bold"),
        title = element_text(face = "bold"))

jan24
```

Statcast distances vs. straight-line route distances

5,000 randomly sampled fly balls from the 2024 season

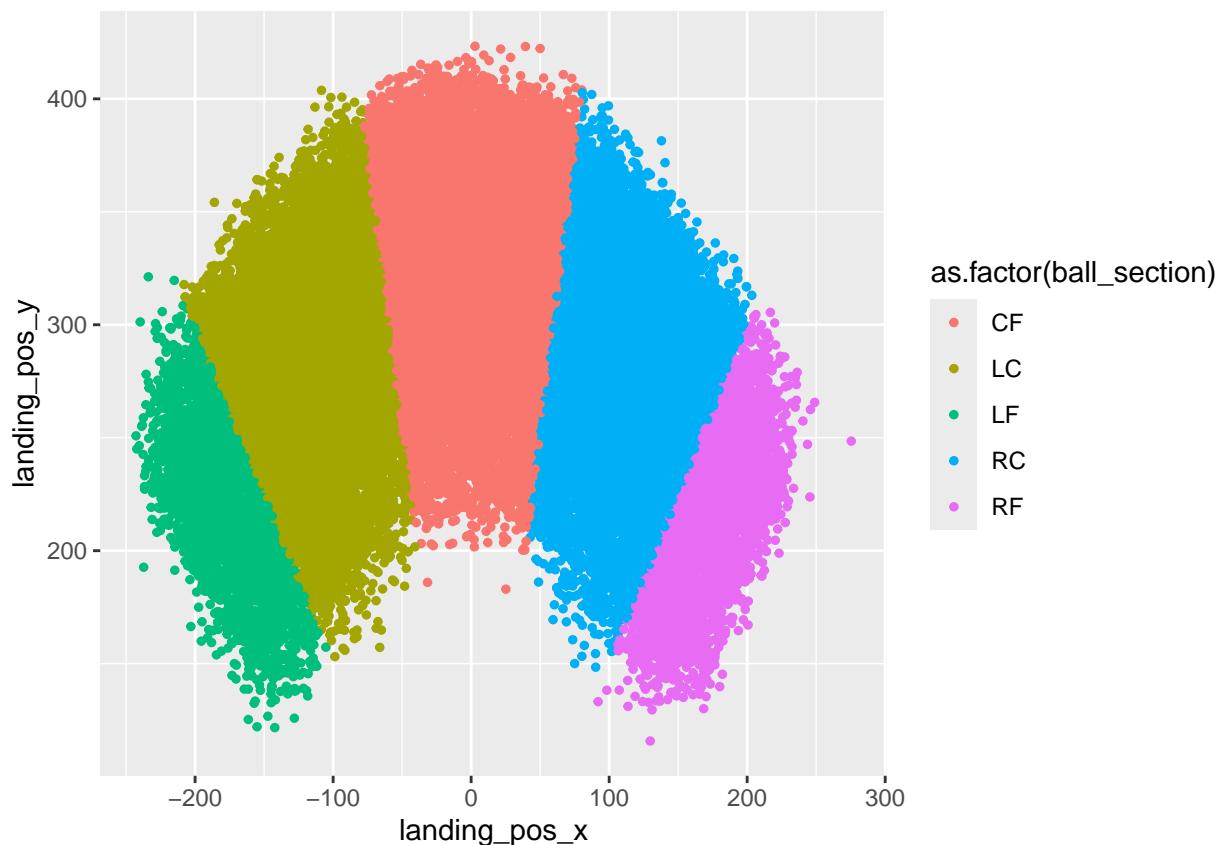


```
ggsave("../figures/jan24.png", plot = jan24, height = 4, width = 6)
```

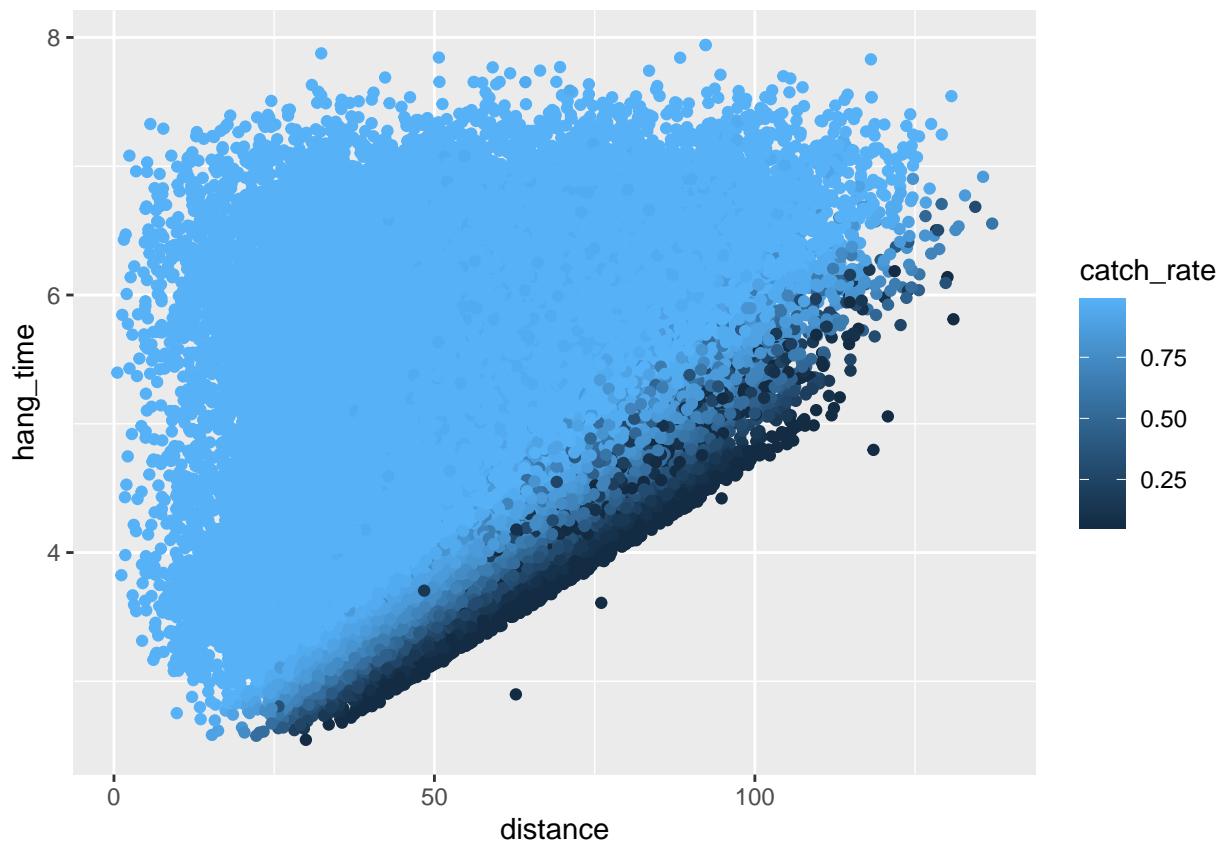
Scratch

```
players_to_keep <- of_catch_prob_2024 %>% count(player) %>% filter(n >= 50) %>% pull(player)
df <- of_catch_prob_2024 %>%
  filter(player %in% players_to_keep) %>%
  filter(stars < 6) %>%
  mutate(route_distance = sqrt((landing_pos_x - start_pos_x)^2 + (landing_pos_y - start_pos_y)^2))
  filter(abs(route_distance - distance) < 5) %>%
  mutate(close_to_wall = as.factor(abs(ball_distance - relevant_wall_distance) < 5))
model <- glm(out ~ pos*route_direction + wall + route_distance + hang_time + stadium + player,
            family = "binomial", data = df)
```

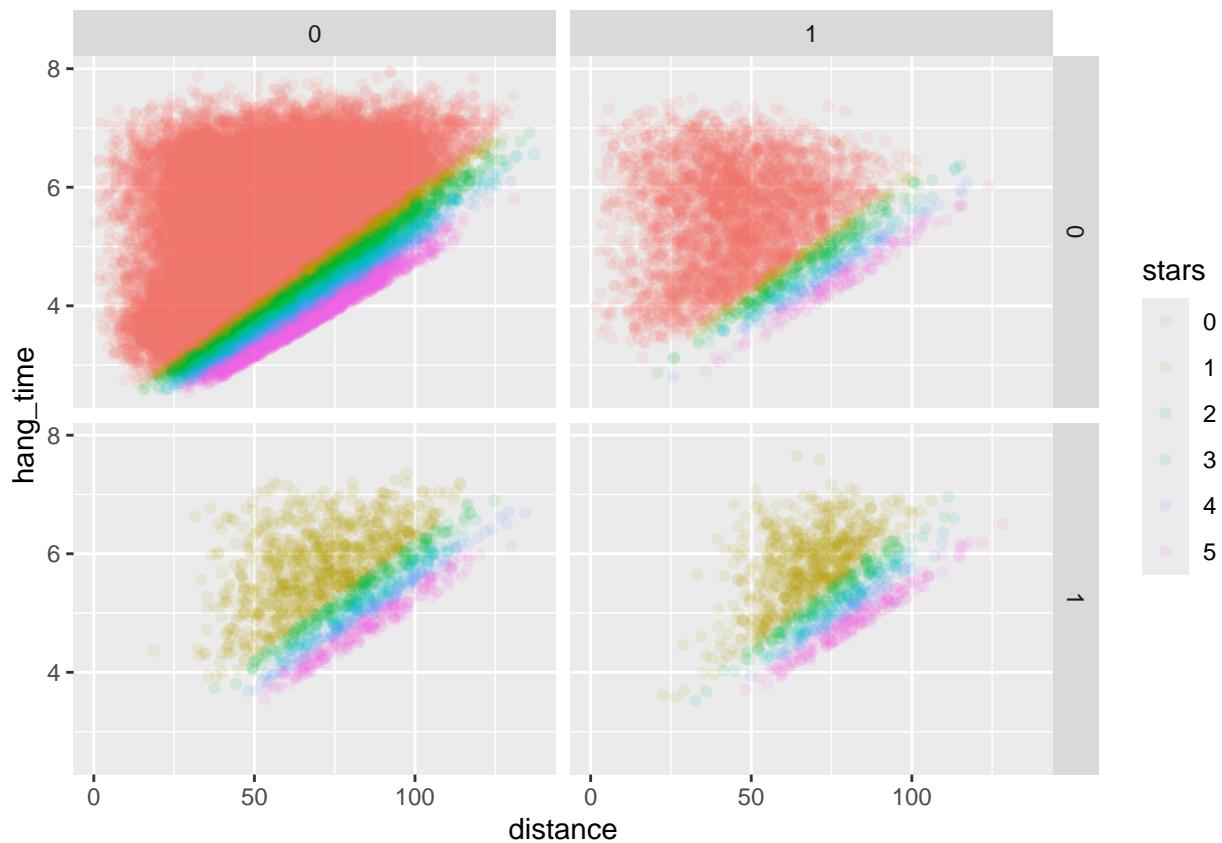
```
of_catch_prob_2024 %>%
  ggplot(aes(x = landing_pos_x, y = landing_pos_y, col = as.factor(ball_section))) +
  geom_point(alpha = 1, size = 1)
```



```
of_catch_prob_2024 %>%
  ggplot(aes(x = distance, y = hang_time, col = catch_rate)) +
  geom_point(alpha = 1)
```



```
of_catch_prob_2024 %>%
  filter(stars <= 5) %>%
  mutate(stars = as.factor(stars)) %>%
  ggplot(aes(x = distance, y = hang_time, col = stars)) +
  geom_point(alpha = 0.1) +
  facet_grid(rows = vars(wall), cols = vars(back))
```



```
of_catch_prob_2024 %>%
  filter(stars <= 5) %>%
  mutate(stars = as.factor(stars)) %>%
  ggplot(aes(x = distance, y = hang_time, col = catch_rate)) +
  geom_point(alpha = 0.1) +
  facet_grid(rows = vars(wall), cols = vars(back))
```

