NHL Shots per Goal Model

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In the NHL, goalies are arguably one of the most teammembers. Most deep postseason runs rely on consistent goalie play. However, being able to compare goalies tends to be difficult, since consistency is extremely hard for a goalie. Few goalies have been consistent their entire career. Of the modern day goalies, very few exemplify extreme consistency: Henrik Lundqvist, Marc-Andre Fleury, Roberto Luongo and Jonathan Quick to name a few.

In this document, I'll be detailing an analysis and seeing how it pertains to consistency. The data used has been taken from MoneyPuck.

Data Formatting

So, let's load in our data:

```
data_2017 = read.csv("data/2017.csv")
```

We'll be starting with the 2017-2018 season. Since we have an extremely large amount of data, we need to clean it up. We'll only be looking at regular season games, initially, so we can start by subsetting our data on that.

```
regular_season_2017 = subset(data_2017, isPlayoffGame == 0)
```

Some important columns we need to keep are:

- xCord
- yCord
- xCordAdjusted
- yCordAdjusted
- shotAngle
- shotAngleAdjusted
- shotDistance
- playerPositionThatDidEvent
- goalieIdForShot
- goalieNameForShot
- shooterPlayerId
- shooterName
- game_id

We'll rename some of the columns, so here is a handy table of the old column names and the new column names.

Old Column Name	New Column Name
xCord	x
yCord	y
xCordAdjusted	x_adj
yCordAdjusted	y_adj
shotAngle	angle
shotAngleAdjusted	angle_adj
goal	goal

Old Column Name	New Column Name
goalieIdForShot	goalie_id
goalieNameForShot	goalie_name
shooterPlayerId	skater_id
shooterName	skater_name
playerPositionThatDidEvent	pos
game_id	game

Now, let's create a new dataframe with just those columns.

```
analysis_2017 = data.frame(x = regular_season_2017$xCord,
                           y = regular_season_2017$yCord,
                           x_adj = regular_season_2017$xCordAdjusted,
                           y_adj = regular_season_2017$yCordAdjusted,
                           angle = regular_season_2017$shotAngle,
                           angle_adj = regular_season_2017$shotAngleAdjusted,
                           goal = regular_season_2017$goal,
                           goalie_id = regular_season_2017$goalieIdForShot,
                           goalie_name = regular_season_2017$goalieNameForShot,
                           skater_id = regular_season_2017$shooterPlayerId,
                           skater_name = regular_season_2017$shooterName,
                           pos = regular_season_2017$playerPositionThatDidEvent,
                           game = regular_season_2017$game_id)
```

With this `analysis_2017` dataframe, we can start looking at a proposed statistic: shots per goal.

Shots Per Goal

Shots per goal is a new statistic. Initially, when I had this idea, it was only for goalies. This article details an initial attempt at analyzing what a shot per goal means. In that initial analysis, I looked at several goalies and tried to determine if there was any significance in what a shot per goal meant. However, now, with further thought, we'll be looking at what a shot per goal means to more than just goalies.

Goalie Aspect

Let's start be looking at a few select goalies from the 2017-2018 season:

1. Braden Holtby
2. Marc-Andre Fleury
3. Connor Hellebuyck
4. Carey Price
5. Andrei Vasilevskiy
6. Robin Lehner
7. Antti Niemi
8. Jaroslav Halak
9. Peter Budaj
10. Jacob Markstrom

To start, we need a function that will take a goalie's name and return all their data. So, let's write our specified subset function:

```
get_goalie_data <- function(data, name) {
    subset(data, goalie_name == name)
}
```

So, let's now start with Brayden Holtby:

```
holtby = get_goalie_data(analysis_2017, "Braden Holtby")
```

Shots per Goals for a Season

With this data, we can now calculate a few shot per goal stats. Let's start with the most basic: shots per goal for the entire season.

```
calculate_spg = function(data) {
    total_shots = length(data$goal)
    temp = subset(data, goal == 1)
    total_goals = length(temp$goal)
    if (total_goals == 0) {
        200
    } else {
        total_shots / total_goals
    }
}
```

Note that if a goalie has a shutout, the SPG will be 200. This is due to R using Inf and not throwing an error.

Now with this function, let's calculate the total shots per goal for the 2017-2018 season for Braden Holtby.

```
holtby_spg_season = calculate_spg(holtby)
```

We see that Holtby gives up one goal per 15.339869281 shots. We can calculate the season shots per goal for each goaltender now.

```
fleury = get_goalie_data(analysis_2017, "Marc-Andre Fleury")
fleury_spg_season = calculate_spg(fleury)

hellebuyck = get_goalie_data(analysis_2017, "Connor Hellebuyck")
hellebuyck_spg_season = calculate_spg(hellebuyck)

price = get_goalie_data(analysis_2017, "Carey Price")
price_spg_season = calculate_spg(price)

vasilevskiy = get_goalie_data(analysis_2017, "Andrei Vasilevskiy")
vasilevskiy_spg_season = calculate_spg(vasilevskiy)

lehner = get_goalie_data(analysis_2017, "Robin Lehner")
lehner_spg_season = calculate_spg(lehner)

niemi = get_goalie_data(analysis_2017, "Antti Niemi")
niemi_spg_season = calculate_spg(niemi)

halak = get_goalie_data(analysis_2017, "Jaroslav Halak")
halak_spg_season = calculate_spg(halak)

budaj = get_goalie_data(analysis_2017, "Peter Budaj")
budaj_spg_season = calculate_spg(budaj)
```

```
markstrom = get_goalie_data(analysis_2017, "Jacob Markstrom")
markstrom_spg_season = calculate_spg(markstrom)
```

Let's take a look at what the results are:

Goalie	Shots per Goal
Fleury	19.08
Hellebuyck	18.3076923077
Price	13.4864864865
Vasilevskiy	16.656626506
Lehner	14.8661971831
Niemi	15.9523809524
Halak	14.65625
Budaj	10.7777777778
Markstrom	15.9868421053

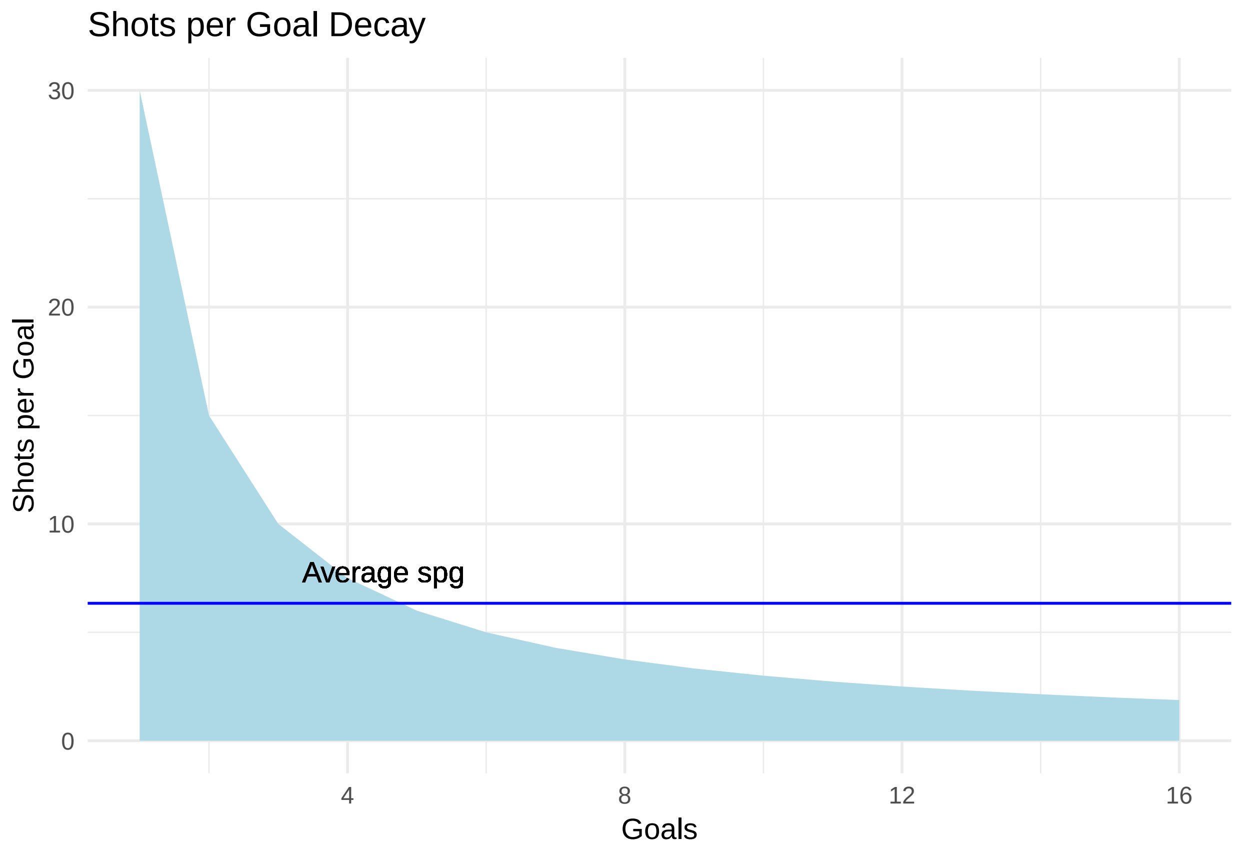
With each of these shots per goal calculations, we can begin to delve deeper into what a shot per goal (SPG) means for a goalie.

A Mathematical Aside

Ideally, during a hockey game, a goalie would like to have a shutout. A shutout, the best goalie performance possible, would equate to an infinite SPG Now, let's continue this hypothetical exercise. Let us say that our goalie faces a total of 30 shots per game, a figure that now seems quite average in the NHL. With a shutout, the SPG is infinite. With one goal allowed, the SPG will drop down to 30. With another goal allowed, the spg drops to 15. Here is a table which depicts the decay of SPG as goals are allowed for a theoretical 30 shot game:

Goals Allowed	Shots per Goal (30 shots)
0	infinite
1	30
2	15
3	10
4	7.5
5	6
6	5

If one were to plot this trend, it would look like this:



Mathematically speaking, we are able to formulaically determine the equation of this curve. We see that this curve is:

$$spg(shots = 30, goals) = \frac{shots}{goals} = \frac{30}{goals}$$

Therefore, whenever we take the limit to determine the lower bound of this function, we see that the lowest possible SPG is:

$$\lim_{goals \to \infty} spg(shots = 30, goals) = \lim_{goals \to \text{inf}} \frac{30}{goals} = 0$$

Therefore, we now know that the lowest possible SPG is 0.

Understanding Shots Per Goal

In the NHL, a goalie (and a team ideally) strives to lower his goals against average (GAA). However, given the nature of GAA, it can be misleading. Similar to a pitchers ERA, GAA is a general stat. It does not give insight into his performance.

For example, a goalie could have a GAA of 3.0 on a given night, but saved 45 or 48 shots. A GAA of 3.0 is considered not very good in the current NHL, but the goalie played exceptionally well given that he had a 93.75% save percentage. Whenever GAA is paired with save percentage, we are given a better picture. However, this picture is still slightly misleading.

Now, let's look at the other extreme; a goalie has a GAA of 1.0 for a game, but only faced 20 shots. With this, we are looking at a GAA of 1.0 and a save percentage of 90.00%. The GAA says the goalie is elite, but the save percentage says the goalie is a benchwarmer. Pairing GAA and save percentage will only take an analysis so far, but there is more to look at.

If we add SPG into the picture, we might be able to gain more insight into the goalie's performance. Let's revist our goalie with a 3.00 GAA and 93.75% save percentage. Since he faced a 48 shots and gave up 3 goals, he has a SPG of 16.0. Our goalie on average will save 16 shots before letting up a goal. On a good day, that means a period or two of shutout hockey. On a bad day, they let up a goal per period.

Now, let's revisit our GAA of 1.0 and save percentage of 90.00% goalie. His SPG, given he faced 20 shots and gave up 2 goals, is 10.0. So, every 10 shots, we expect a goal to be given up. Let me make a table to help understand the differences between the two goalies.

Goalie	GAA	Save Percentage	Shots Per Goal	Shots Faced
A	3.00	93.75%	16.0	48
B	1.00	90.00%	10.0	20

From here, we can determine which goalie is better. Categorically, goalie A wins as he has a better save percentage and SPG. Though goalie B has a better GAA, we know through SPG and save percentage, that goalie B will give up more goals given a higher shot volume.

Drawbacks of Shots per Goal

An immediate drawback of SPG is that is does not take the defense into account. However, both GAA and save percentage, also have this drawback. Taking defense out of the picture in a statistic may be not as useful as assessing the goalie by himself takes a large chunk of a team out of the statistic. Both GAA and save percentage reflect on the defensive play of team since a goalie can only do so much. A perfect example of this is Cam Talbot in 2016-2017. Cam Talbot started **73** games for the Edmonton Oilers and put up a 2.39 GAA and 91.9% save percentage (numbers taken from Hockey Reference). These numbers are not spectacular, but it does reflect on the team's defense: it was terrible. His SPG that season was 12.38. This SPG additionally reflects on his team's defensive play.

Additionally, SPG does not account for shot attempts, only shots on goal. There is a significant difference between the two, as a defense can be excellent at shot blocking. However, their goalie may not be as good, so the defense is forced to block shots more. This may lead to a slightly inflated SPG. In the future, more research can be done on this, leading to a new statistic: shot attempts per goal (SaPG). Currently, I do not have the data to calculate this. However, I do suspect that SaPG can be used not only as a metric to determine the effectiveness of a goalie, but also determine how good a defense is.

Determining Shots Per Goal for a Single Game

In our goalie data, we have a column called `game`. This column tells us what game we are looking at. So, we can subset on a specific game and determine the shots per goal that game. Let's write a few functions to help us do that.

```
get_games = function(data) {
    unique(data$game)
}

get_game_data = function(data, game_id) {
    subset(data, game == game_id)
}
```

With the use of some functional programming, we can create a list of dataframes for each game.

```
get_all_games = function(data) {
    games = get_games(data)
    Map(function(x) get_game_data(data, x), games)
}
```

Note that get_all_games doesn't return a vector, but a large list.

Now, with our calculate_spg function, we can get the SPG for each game. Here's a function that does that:

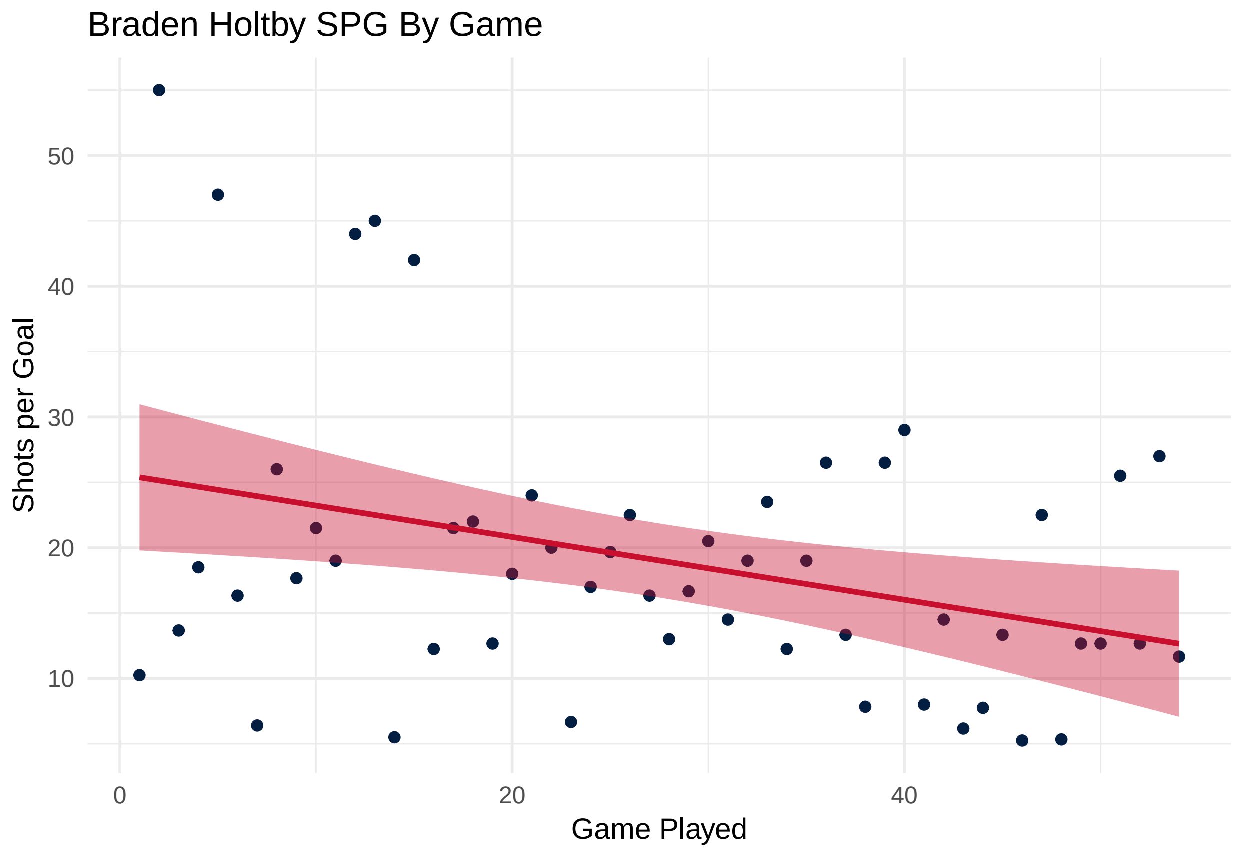
```
get_spg_games = function(data) {
    gameframes = get_all_games(data)
    gamespg = map(gameframes, function(x) calculate_spg(x))
    unlist(gamespg, use.names = FALSE)
}
```

Please note that the map function used here comes from the purrr library.

With get_spg_games, we can start looking at trends in performances. Let's start by first calculating SPG for each game for each of our select goalies.

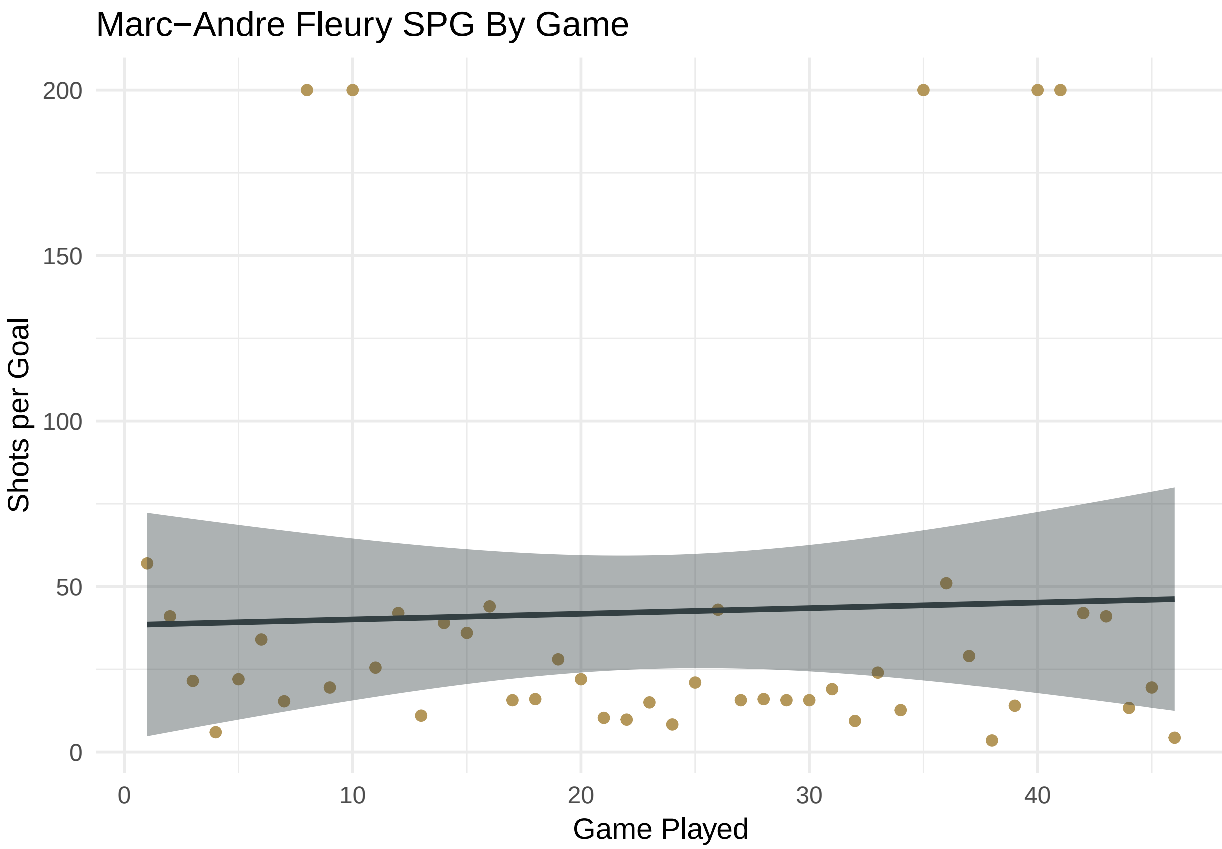
```
holtby_spg_games = get_spg_games(holtby)
fleury_spg_games = get_spg_games(fleury)
hellebuyck_spg_games = get_spg_games(hellebuyck)
price_spg_games = get_spg_games(price)
vasilevskiy_spg_games = get_spg_games(vasilevskiy)
lehner_spg_games = get_spg_games(lehner)
niemi_spg_games = get_spg_games(niemi)
halak_spg_games = get_spg_games(halak)
budaj_spg_games = get_spg_games(budaj)
markstrom_spg_games = get_spg_games(markstrom)
```

Let's take a look at these goalies: Holtby, Fleury, Price, Lehner, and Markstrom. Here's the trend of Braden Holtby's SPG by game.



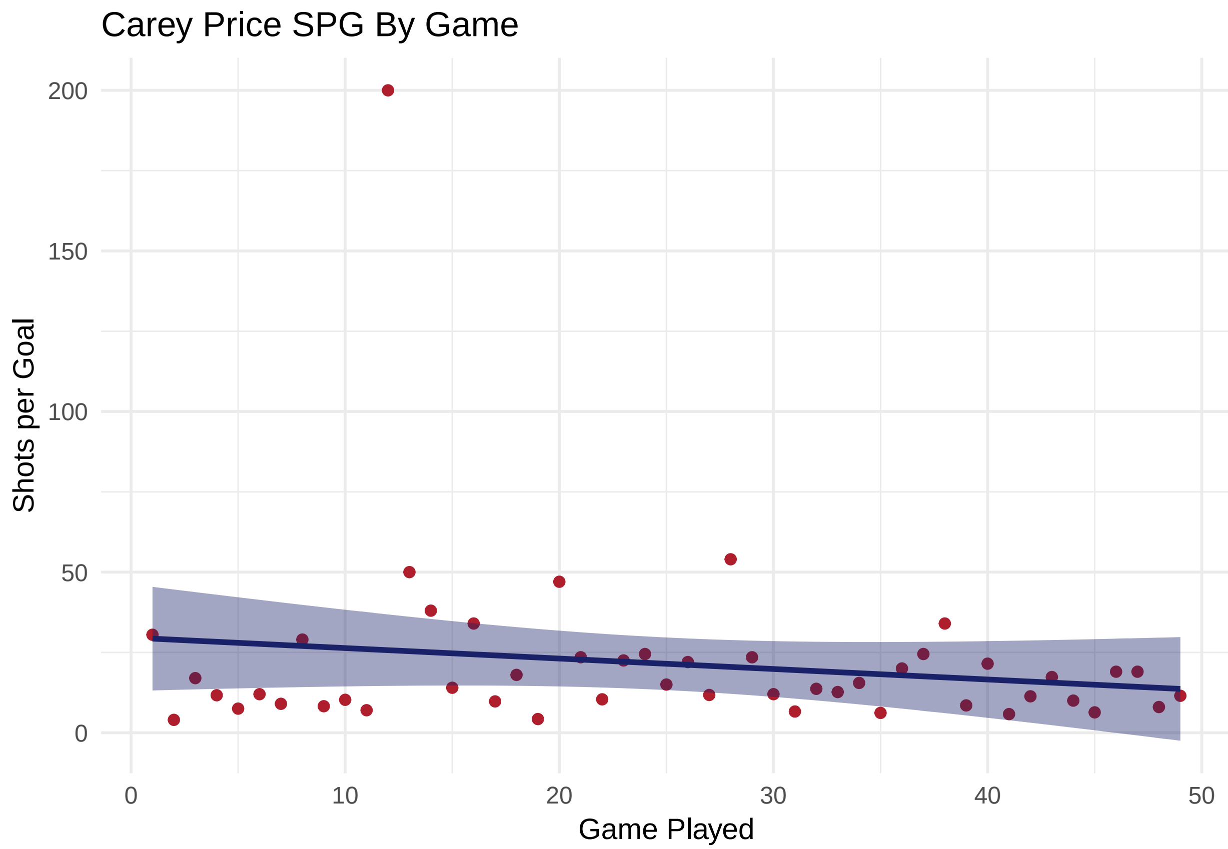
In this graph, we see that each point is Holtby's SPG for a specific game. The line is a linear model which shows that over the season, Holtby seemed to follow a decreasing linear trend.

Let's now look at someone who he faced in the Stanley Cup finals: Marc-Andre Fleury



Fleury's trend seems to be more stable, unlike Holtby. However, Fleury had 5 shutouts, which are seen as 200 instead as Inf. This leads to there being some minor skewing in the linear model.

A final player I'd like to look at is Carey Price. Price is supposed to be a Vezina caliber goaltender every year. However, injuries have set him back. Let's see how his trend is for the 2017-2018 season.



Similar to Holtby, Price has a decreasing trend in his SPG. However, Price's decreasing trend is less than Holtby's.

Shots per Goal from Specific Locations

In my initial attempt at analyzing shots per goal, I determined three danger zones in the attacking end: low, medium, and high. In the goalie dataframe, we've included x and y coordinates since these zones are in specific locations. With landmarks on the ice, like the slot and circles, I determined which were low, medium, and high danger. Here is was I determined:

Position	X Coordinate (Adj)	Y Coordinate (Adj)	Danger Level
Slot	From 40 to 90	From -22 to 22	High
Left Circle	From 32 to 82	From -43 to 7	Medium
Right Circle	From 32 to 82	From 7 to 43	Medium
Point	From 20 to 35	From -43 to 43	Low

I do know that this is not as accurate as it could be. There is significantly more areas that can be studied, such has high and low slot, net front, and the half-walls. That being said, this is not meant to be an in-depth analysis; instead I am looking for generic trends.

So, without further ado, let's start by writing a few subsetting functions to help us look at the trends in shots per goal.

```
get_low_danger = function(data) {
    subset(data,
           x_adj >= 20 & x_adj <= 35 & y_adj <= 43 & y_adj >= -43)
```

```
}

get_medium_danger = function(data) {
    subset(data,
           x_adj >= 32 & x_adj <= 82 &
            ((y_adj >= 7 & y_adj <= 43) | (y_adj <= -7 & y_adj >= -43)))
}

get_high_danger = function(data) {
    subset(data,
           x_adj >= 40 & x <= 90 & y_adj >= -22 & y_adj <= 22)
}
```

With these functions, we can start looking at how a goalie performs when a shot is taken from a certain location. Let's start by writing a few more functions which will calculate the SPG for a certain danger level.

```
low_danger_spg = function(data) {
    calculate_spg(get_low_danger(data))
}

medium_danger_spg = function(data) {
    calculate_spg(get_medium_danger(data))
}

high_danger_spg = function(data) {
    calculate_spg(get_high_danger(data))
}
```

With these functions, let's compute the SPG for each danger level for each goalie now.

Low Danger Shots

```
holtby_low_spg = low_danger_spg(holtby)
fleury_low_spg = low_danger_spg(fleury)
hellebuyck_low_spg = low_danger_spg(hellebuyck)
price_low_spg = low_danger_spg(price)
vasilevskiy_low_spg = low_danger_spg(vasilevskiy)
lehner_low_spg = low_danger_spg(lehner)
niemi_low_spg = low_danger_spg(niemi)
halak_low_spg = low_danger_spg(halak)
budaj_low_spg = low_danger_spg(budaj)
markstrom_low_spg = low_danger_spg(markstrom)
```

Medium Danger Shots

```
holtby_medium_spg = medium_danger_spg(holtby)
fleury_medium_spg = medium_danger_spg(fleury)
hellebuyck_medium_spg = medium_danger_spg(hellebuyck)
price_medium_spg = medium_danger_spg(price)
vasilevskiy_medium_spg = medium_danger_spg(vasilevskiy)
lehner_medium_spg = medium_danger_spg(lehner)
niemi_medium_spg = medium_danger_spg(niemi)
halak_medium_spg = medium_danger_spg(halak)
```

```
budaj_medium_spg = medium_danger_spg(budaj)
markstrom_medium_spg = medium_danger_spg(markstrom)
```

High Danger Shots

```
holtby_high_spg = high_danger_spg(holtby)
fleury_high_spg = high_danger_spg(fleury)
hellebuyck_high_spg = high_danger_spg(hellebuyck)
price_high_spg = high_danger_spg(price)
vasilevskiy_high_spg = high_danger_spg(vasilevskiy)
lehner_high_spg = high_danger_spg(lehner)
niemi_high_spg = high_danger_spg(niemi)
halak_high_spg = high_danger_spg(halak)
budaj_high_spg = high_danger_spg(budaj)
markstrom_high_spg = high_danger_spg(markstrom)
```

Here's a table showing each of the goalies with their low, medium, and high SPG values.

Goalie	Low Danger SPG	Medium Danger SPG	High Danger SPG
Holtby	113.5	25.3396226415	10.3475177305
Fleury	200	28.5454545455	13.2365591398
Hellebuyck	51.8	25.7397260274	12.5271317829
Price	98.5	20.4838709677	8.572519084
Vasilevskiy	99.5	23.6202531646	11.6486486486
Lehner	30.2857142857	23.9642857143	9.8991596639
Niemi	45	22.3928571429	12
Halak	47.25	20.4225352113	11.4285714286
Budaj	200	16.25	7.2
Markstrom	40.4	21.7857142857	11.5692307692

As we can see, there seems to be a distiction between elite goalies (like Holtby, Fleury, and Vasilevskiy) and struggling goalies (Niemi, Halak, and Markstrom).

Skater Aspect

To be done.

Positional Aspect

To be done.

Locational Aspect

To be done.

Specific Player Analysis

Matt Murray

Matt Murray is not even 25 yet and he has already won 2 Stanley Cups. In his young career, Murray has displayed phenomenal poise in net. However, he has also battled concussions and various injuries. This season, Murray has somewhat struggled. Due to injury or something else, Murray was placed on injured reserve in November 2018 and was re-instated a month later. Since his comeback, Murray has been on fire. I want to see how Murray has grown as a goalie during his 2016-2017 campaign, 2017-2018 campaign, his current season.

Let's start with simply loading in the data. We already have the 2017-2018 data, so let's load in his 2016-2017 data.

```
data_2016 = read.csv("data/2016.csv")
regular_season_2016 = subset(data_2016, isPlayoffGame == 0)
analysis_2016 = data.frame(x = regular_season_2016$xCord,
                           y = regular_season_2016$yCord,
                           x_adj = regular_season_2016$xCordAdjusted,
                           y_adj = regular_season_2016$yCordAdjusted,
                           angle = regular_season_2016$shotAngle,
                           angle_adj = regular_season_2016$shotAngleAdjusted,
                           goal = regular_season_2016$goal,
                           goalie_id = regular_season_2016$goalieIdForShot,
                           goalie_name =
                            regular_season_2016$goalieNameForShot,
                           skater_id = regular_season_2016$shooterPlayerId,
                           skater_name = regular_season_2016$shooterName,
                           pos = regular_season_2016$playerPositionThatDidEvent,
                           game = regular_season_2016$game_id)

murray_2016 = get_goalie_data(analysis_2016, "Matt Murray")
murray_2017 = get_goalie_data(analysis_2017, "Matt Murray")
```

With this data, we can select Murray's data and start looking at his trends. Let's get all his import SPG data now.

```
murray_spg_2016 = calculate_spg(murray_2016)
murray_spg_2017 = calculate_spg(murray_2017)

murray_spg_games_2016 = get_spg_games(murray_2016)
murray_spg_games_2017 = get_spg_games(murray_2017)

murray_low_spg_2016 = low_danger_spg(murray_2016)
murray_medium_spg_2016 = medium_danger_spg(murray_2016)
murray_high_spg_2016 = high_danger_spg(murray_2016)

murray_low_spg_2017 = low_danger_spg(murray_2017)
murray_medium_spg_2017 = medium_danger_spg(murray_2017)
murray_high_spg_2017 = high_danger_spg(murray_2017)
```

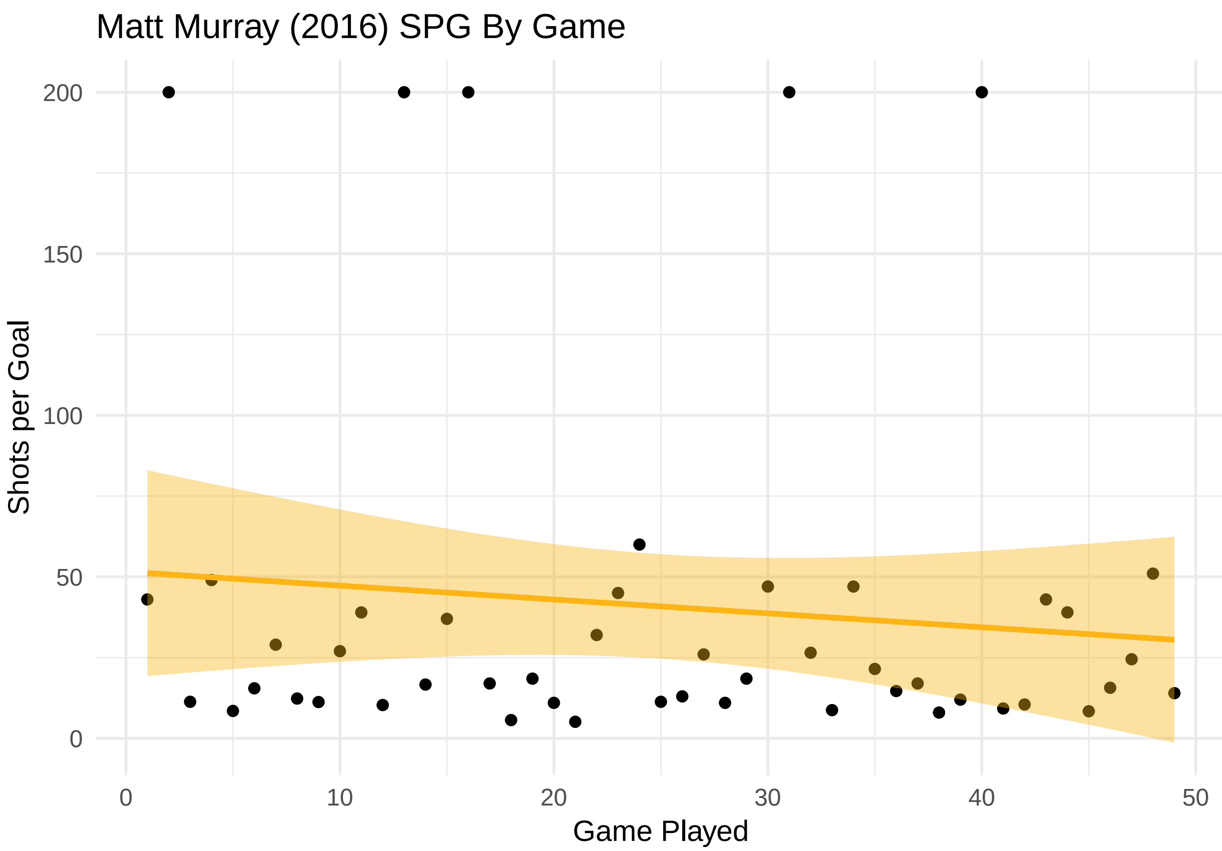
With all these calculations, we can start to look at some trends. Here is a table so we can inspect the data:

Season	SPG	Low Danger SPG	Medium Danger SPG	High Danger SPG
2016	17.5315315315	200	30.675	10.2231404959

Season	SPG	Low Danger SPG	Medium Danger SPG	High Danger SPG
2017	14.3233082707	116	17.5211267606	10.2231404959

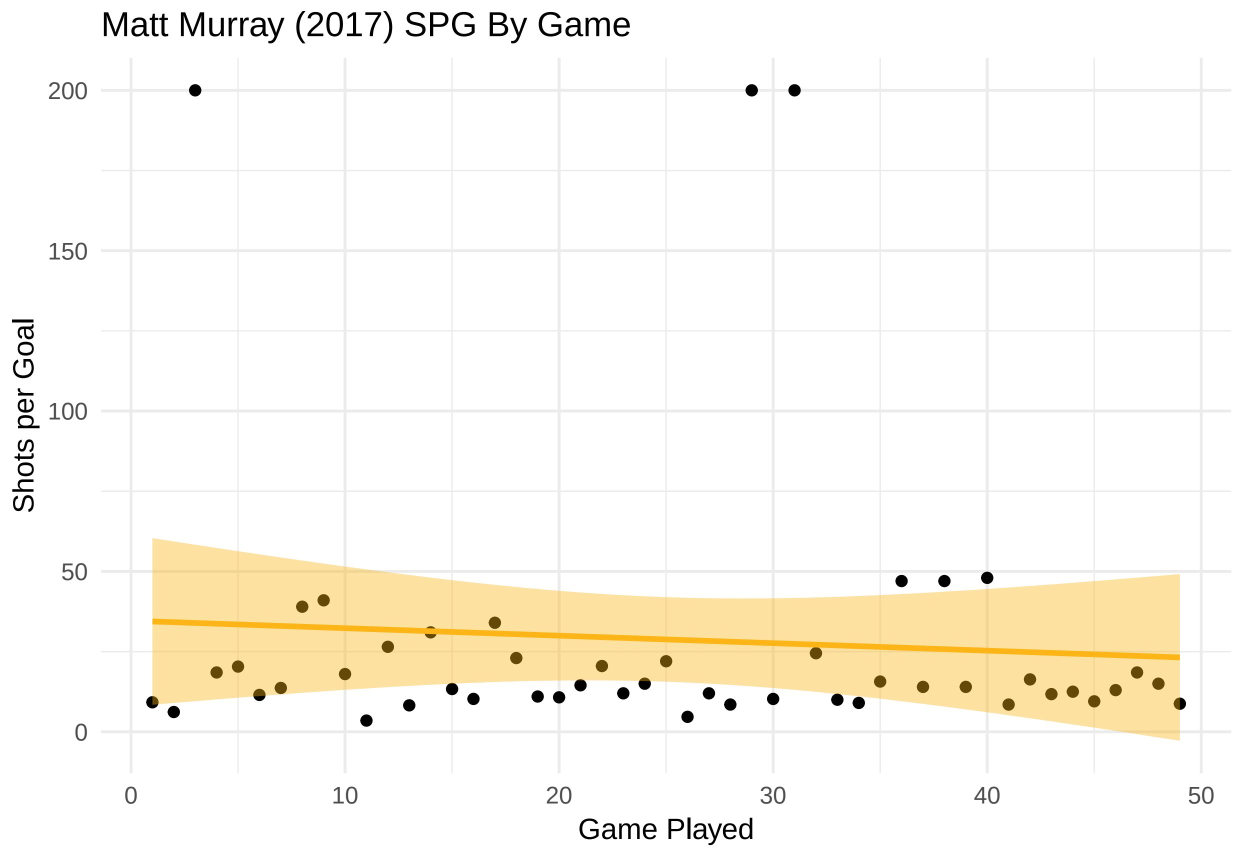
From this, we can see that Murray has always been strong against low danger shots. However, there is a downward trend in his total SPG as well as medium danger SPG shots. With a difference of 13.1538732394, there should be some concern for Murray.

Let's now take a look at his trends for each game he played for both season. First, we'll look at 2016-2017.



We can see that Murray followed most trends that other goalies did: a decreasing trend. However, I believe this trend is slightly skewed as Murray did have 5 shutouts and therefore 5 outliers in the data. That being said, The shutouts are pretty evenly spaced in the data, skewing the data up completely. This does not discount the fact that Murray performed exceptionally well that season.

Let's now take a look at 2017-2018.



Unlike his 2016-2017 season, Murray struggled for stretches, but then had elite play for othe stretches. With 3 shutouts, the data is slightly skewed, but not by that much. Murray in 2017 almost had a stable neutral trend, but still tailed off near the end of the season.

Murray's change in performance can be attributed to multiple factors. First, personal issues during the 2017-2018 season. Second, injuries plagued him the entire season. Finally, a *theoretical* sophomore slump.

Casey DeSmith

To be done.