It's 2020, and predictive football analytics are quite mature. At The Power Rank, I use a wide variety of statistics such as margin of victory and success rate. After proper schedule adjustments, these metrics take you a long way towards predicting the outcome of games.

But what do these metrics not consider? What factor should be considered in addition to a predictive model? Turnovers. In particular, the absence of turnovers. Let me explain.

Interceptions make a huge impact on a game. Jameis Winston throws a pass, the football gets deflected, and now anything can happen. Does it drop harmlessly to the ground? Or does it land in the hands of a defender who runs the other way?

A team that has more interceptions than their opponent wins 76% of NFL games. In addition, a regression analysis shows that an interception is worth about five points.

What happens when Jameis gets lucky with interceptions? For a stretch of games, he throws a lot of bad passes, but the defense drops these gifts. A points based metric will overrate this offense. These metrics can't see the interceptions that should have tilted the scoreboard against Jameis. When the interceptions inevitably do come, the metrics will lower the rating on this offense.

Here, I will discuss how to predict interceptions.

- First, I'll talk about why they're so difficult to predict.
- Then, I'll get into the difference between predictability and skill and how this applies to interceptions. This suggests not giving up on predicting interceptions.
- Next, I'll discuss the hidden variable that predicts interceptions.
- Finally, I'll apply this analysis for NFL quarterbacks in 2020.

Let’s get started.

Why are interceptions difficult to predict?

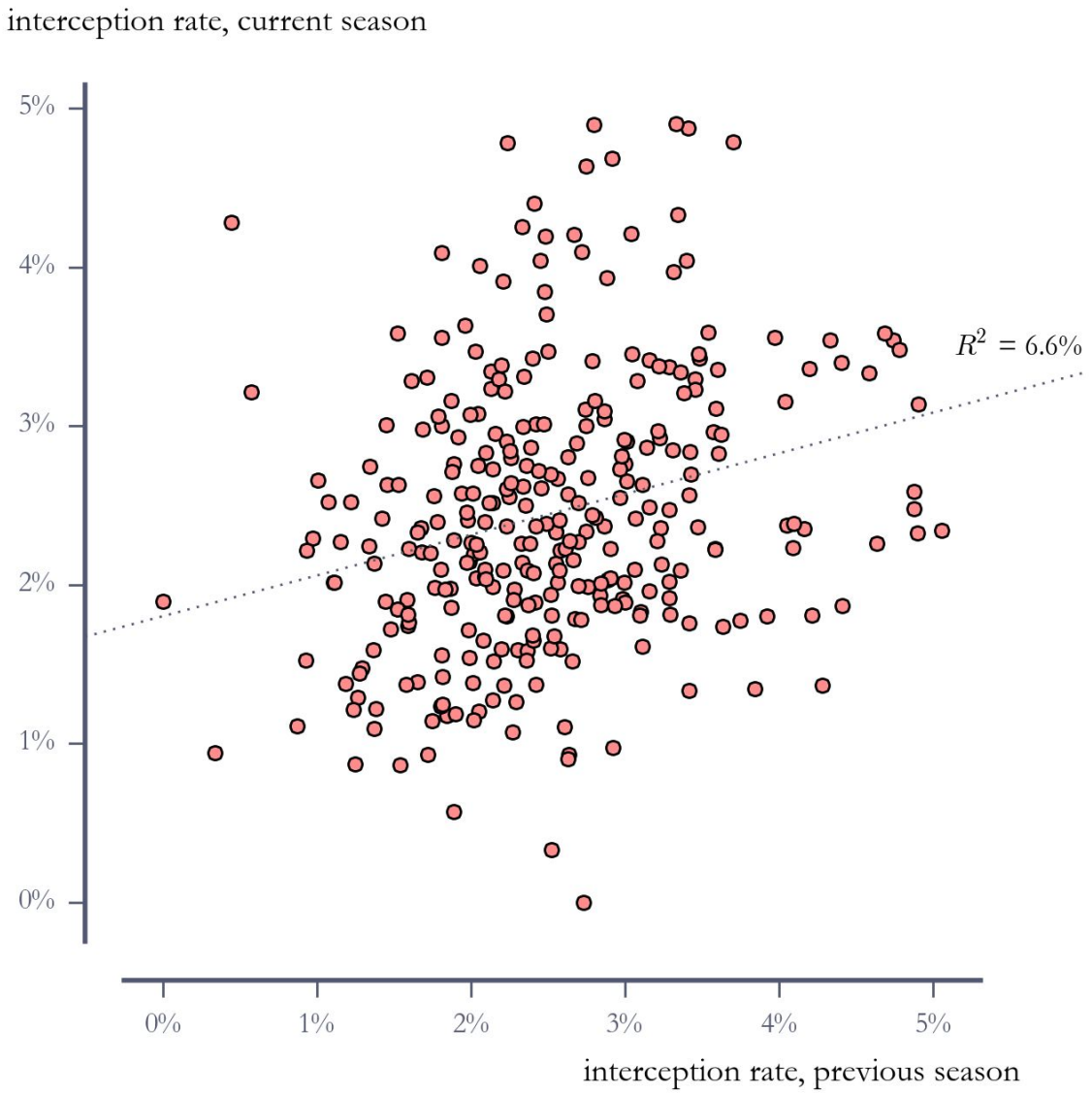
To look at the most basic idea of predictability, consider a quarterback's interception rate, or interceptions divided by pass attempts. We ask how sticky this quarterback statistic is from season to season.

Stickiness is determined by calculating the correlation of interception rate from one season to the next. This analysis considers the 2000 through 2019 seasons, and a quarterback gets included if he has thrown 200 pass attempts in consecutive seasons.

Interception rate the previous season explains only 7% of the variance in interception rate during the current season. To understand this result, think of a plot of data points that correspond to consecutive seasons. The interception rate from the previous season is on the x-axis, or the horizontal axis. The interception rate from the current season, or the variable we would like to predict, is on the y-axis, or the vertical axis.

If interception rate were a good predictor, the data points would hug a line. There would be scatter around the line, since no predictor is perfect. But the data would suggest a clear relationship between the two quantities.

There is no clear relationship between interception rate in consecutive seasons. Interception rate from the previous season explains 7% of the variance in the current season, and this 7% is known as the R-squared value. The plot of the data looks like a Jackson Pollock painting.

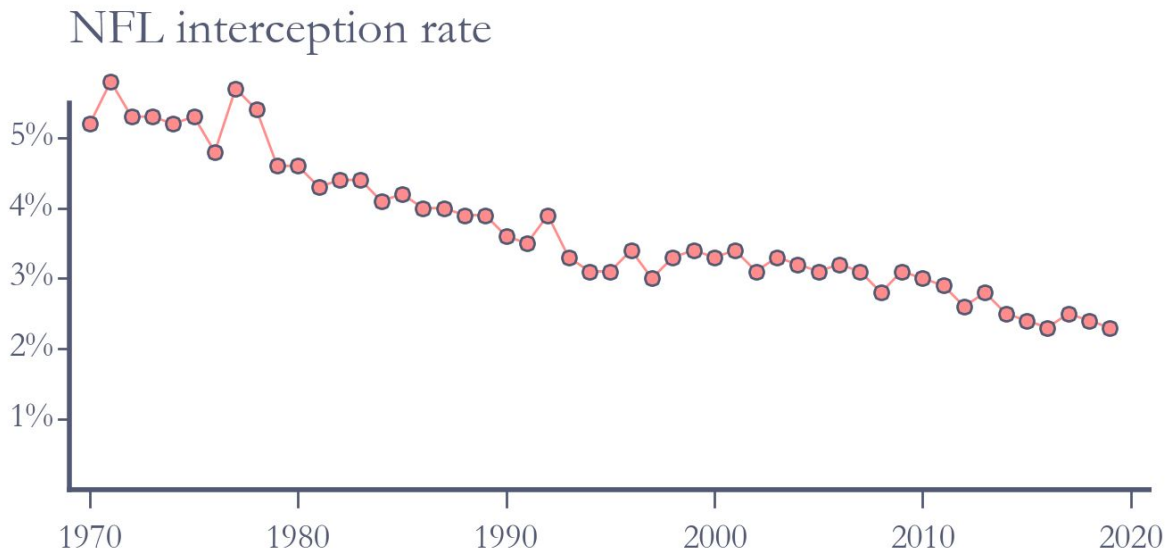


This is frustrating, since it means a quarterback's interception rate from last season can't predict this season. Randomness plays a big role in interception rate from year to year. There is very little predictability.

But are interceptions really that random and unpredictable? Two pieces of evidence suggests otherwise.

First, the interception rate continues to decline in the NFL. Back in the early 1970s, the NFL was a more chaotic environment. From 1970 to 1977, over 5% of passes landed in the hands of the defense in all but one season. In 1978, the NFL changed the rules to make passing easier. For example, a defensive back could now only touch a receiver within five yards of the line of scrimmage. Previously, the defensive back could put his hands on the receiver at anywhere on the field.

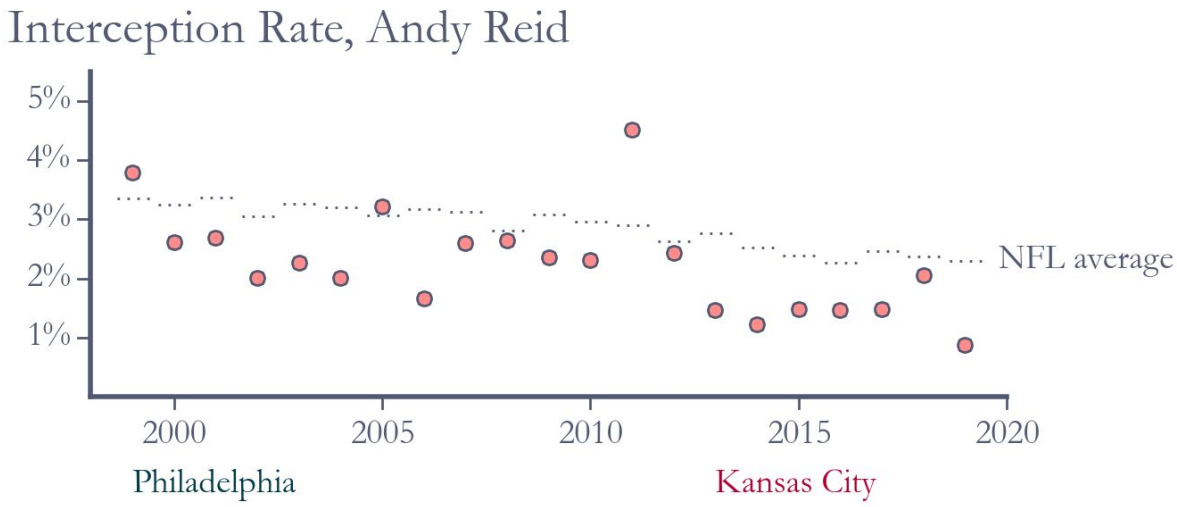
Interception rate has shown a constant, linear decline since these rule changes in 1978. From 2014 to 2019, the NFL has had an average interception rate of 2.4%, less than half the interception rate during the 1970s. Passing continues to get safer. If picks were truly random, this would be unlikely.



Second, consider someone like Andy Reid, who has served as a head coach for 21 seasons in Philadelphia and Kansas City. In only three of those seasons did his quarterback throw a higher than NFL average interception rate. The last of these seasons was 2011 in Philadelphia.

It's one thing if a coach has one amazing quarterback with pinpoint accuracy. However, Reid has kept this rate with a variety of quarterbacks. This includes

Donovan McNabb, Michael Vick, Alex Smith and Patrick Mahomes. This suggests coaches can play a role in reducing interception rates.



There's a third way to look at interceptions that suggests they might be predictable.

In throwing an interception, let’s ask about the relative contribution of skill and luck.

To understand how this works, let's first assume there is zero skill in throwing interceptions. This means that every quarterback has a 2.4% chance of throwing an interception on a pass attempt. If this assumption matches up with data on players, then interceptions would be all luck.

However, this seems improbable. Consider Jameis Winston. Tampa Bay fans had high hopes when he was drafted as the top pick in the 2015 draft. They had even higher hopes in 2019 when Bruce Arians arrived as his head coach.

However, Jameis was a turnover machine in 2019, as he threw interceptions on 4.8% of his pass attempts. This percentage was a little bit of an anomaly. In his career before Arians, he had a 3% interception rate. That's not good, but it's not atrocious like his 2019 rate.

Over his career, Jameis has thrown 2,551 pass attempts. If interceptions were all luck, we would expect his interception rate to be close to the NFL average of 2.4%. With more pass attempts, the more likely his interception rate is close to this average. Remember, the assumption is that interceptions are all luck. This makes the math easy, as the distribution of Jameis' interception rate is something called a binomial distribution.

With enough pass attempts, this distribution looks like a normal distribution, or the bell curve that you often see. For Jameis, this bell curve implies a 2 in 3 chance his interception rate is between 2.1% and 2.7%. This means the width, or standard deviation, is 0.3%. If Jameis threw another two thousand pass attempts, the width would get smaller.

Jameis' actual interception rate is higher than expected from the randomness assumption. During his career, he's averaged a 3.5% interception rate. Based on the width of 0.3%, Jameis is three and a half standard deviations worse than NFL average. That's as bad as the acting of Hayden Christiansen as Anakin Skywalker in Star Wars.

How about the new quarterback in Tampa Bay? Tom Brady has thrown picks on 1.4% of his pass attempts over the last six seasons. Based on the randomness assumption and 5,500 pass attempts, he is four standard deviations better than the NFL average.

These extremes in interception rate suggest a contribution of skill to interceptions. To quantify this, I'm going to use an idea from Michael Maubossian in his book *The Success Equation*. He said that:

Outcome = Skill + Luck

Here, the outcome is interception rate. The skill part is related to the accuracy of the quarterback. A player who can regularly throw a football through a tire 50 yards away will throw fewer interceptions. Aaron Rogers has a 1.1% interception rate since the 2014 season.

A rate that low might not be the best idea. Minimizing interception rate should not be the goal in football. The goal should be to win football games. If a team is down late in the game and needs a touchdown, the optimal strategy is throwing to Davante Adams in double coverage, even though there's a higher chance of a pick. This is better than dumping the ball off to a running back.

In addition to skill, there is luck involved in throwing interceptions. Even the most accurate quarterback will throw an errant pass at times. In addition, the speed of a modern NFL defense forces some tipped passes and pass break ups. The offense has no control over the trajectory of the ball once these plays happen. Despite their best efforts, Tom Brady and Aaron Rogers will never have a zero interception rate.

With the Maubossian model, let's consider the variance of the outcome, or the variance in interception rate. This is given by the following:

Var(Outcome) = Var(Skill) + Var(Luck)

Usually when we take the variance of a linear equation, there's a term that considers the correlation between skill and luck. However, by definition, there is no correlation between skill and luck. Luck, good or bad, does not discriminate between Jameis Winston and Tom Brady.

Before, we looked at the deviation in interception rate for Jameis Winston and Tom Brady. Let's do the same for all quarterbacks the past six seasons. Based on the randomness assumption, we calculate a standard deviation from NFL average. This

depends on the number of pass attempts, and the analysis only includes quarterbacks with 500 pass attempts during this time period.

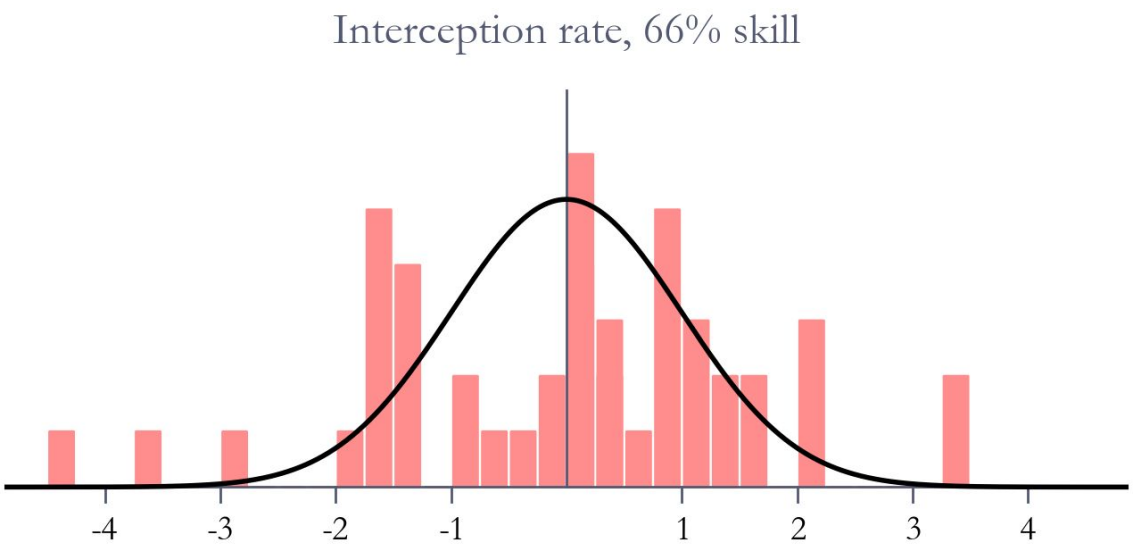
If interceptions were all luck, this player data would produce a bell curve with a width of one. The preliminary analysis suggested a distribution with a larger width. The wider this distribution, the more skill in interceptions.

The key quantity is the fraction of variance in outcome that comes from variance in skill. This is similar to what we looked at with predictability.

With predictability, we were interested in the interception rate for a single season. We reported how much of the variance in this interception rate was explained by interception rate the previous season.

With skill, we consider a player's interception rate over six seasons. We will report how much of the variance in this interception rate is explained by skill. There would be some variance in interception rate due to randomness. The simple Maubossian model attributes the excess variance to skill.

Based on the past six seasons, interception rate is 66% skill. What does that mean?



To put this in perspective, let's look at other quarterback statistics from the same time period. First, consider completion percentage. The analysis shows completion percentage is 86% skill. This means that luck plays a minor role in Drew Brees and his 71% completion percentage the past six seasons. The NFL average has been 63%.

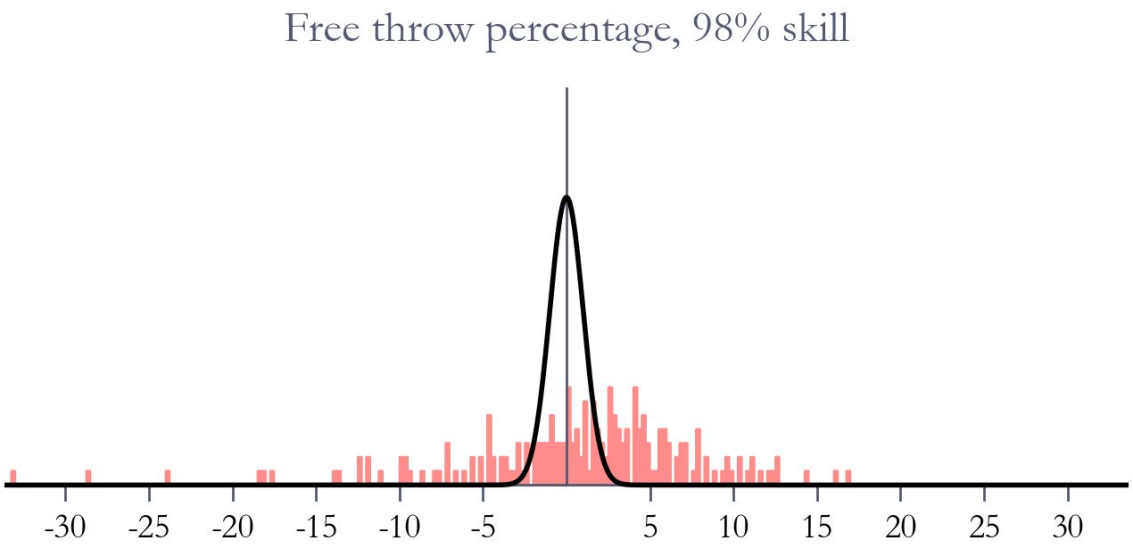
As another example, consider a quarterback's fumble rate on sacks. I looked into this because a large percentage of fumbles occur on sacks. Knowing which quarterbacks fumble at the highest rate would identify a factor that doesn't show up in the points based metrics. It's the same idea that motivated looking at interceptions.

The fumble study didn't turn out like I would have liked, and that's a story for another day. But I did look at the skill in fumble rate on sacks, which considers all fumbles, not only fumbles lost. This isolates the skill for quarterbacks without the randomness in fumble recoveries. Fumble rate on sacks is 49% skill. There is not as much skill in holding onto a football during a sack as with interceptions.

With interceptions, one source of randomness is the defense. To get a better sense for what 66% skill means in the presence of eleven defenders, let's look at an outcome in another sport that comes with and without defense: shooting a basketball. I did a

study on NBA players over the last six seasons. The data set started at the beginning of the 2014 season and ended with the COVID-19 lockdown in 2020.

Free throw shooting percentage is 98% skill. There's no defense, as a free throw involves the shooter and the basket. The difference between Steph Curry and Andre Drummond is clear.



How does this compare to three pointers? Three point shooting percentage is 78% skill. When the shooter steps back from the free throw line and a defense can now alter the shot, luck starts to play a bigger role.

Since throwing interceptions is 66% skill, there is more luck in interceptions than three pointers. However, interceptions and three point shooting are similar in a key way.

Interception rate has low predictability. The interception rate last season explains 7% of the variance in interception rate this season. However, it's 66% skill.

We see the same trend with three point shooting in the NBA. For predictability, last season's three point shooting percentage for a player explains 14.5% of the variance in this year's three point shooting percentage. However, three point shooting is 78% skill.

Interceptions and three point shooting have low predictability but high skill.

This skill in interceptions suggests we should be able to do better at predicting interception rate. To do this, we need to consult a different variable.

In 2014, Bill Connolly wrote a preview for the Houston Cougars. Back in his time at *SB Nation*, Connelly would write a preview for all one hundred twenty some FBS teams.

In this preview, he was looking at quarterback John O'Korn, who had started the previous season as a freshman and won the American Athletic Conference Freshman of the Year. However, Connelly had his concerns about O'Korn. He wrote:

> Luck indeed allowed Houston to keep some games closer than they probably should have; against UCF and Louisville, for instance, opponents picked off just two O'Korn passes while breaking up 17.

The idea is simple: if a quarterback throws a lot of balls into dangerous situations, he will eventually throw some picks. The fraction of these bad balls that end up as interceptions should be constant every year.

John O'Korn had very few bad balls end up as interceptions in 2013. This means that he should throw more interceptions as the rate of interceptions to bad balls regresses

to the mean. At Football Outsiders, Aaron Schatz has also applied this idea to the NFL.

Let's dig a little bit deeper here. The NFL play by play tracks passes defended. This includes three types of events:

1. The pass gets tipped at the line of scrimmage.
2. The ball gets deflected by a defender in coverage.
3. A defender hits the receiver as the ball arrives and jars the ball loose.

These three events get counted as passes defended. In looking at a quarterback, we can track how often he puts a ball in a dangerous situation through these passes defended.

Consider the rate at which a quarterback allows the defense to break up a pass. His passes defended rate is passes defended divided by pass attempts.

First, let's ask about the stickiness of this quantity from year to year. For quarterbacks, last year's passes defended rate explains 20% of the variance in passes defended rate during the current season. That's almost three times as much variance explained as interception rate.

Passes defended rate is not quite as sticky as completion percentage. The previous season's completion percentage explains 28% of the variance in completion percentage during the current season. However, there is a way to enhance passes defended rate to make it more sticky. More on that later.

What about skill versus luck in passes defended? Over the past six seasons, 75% of passes defended rate is explained by skill. This is more than the 66% skill with interception rate but less than the 86% skill with completion percentage.

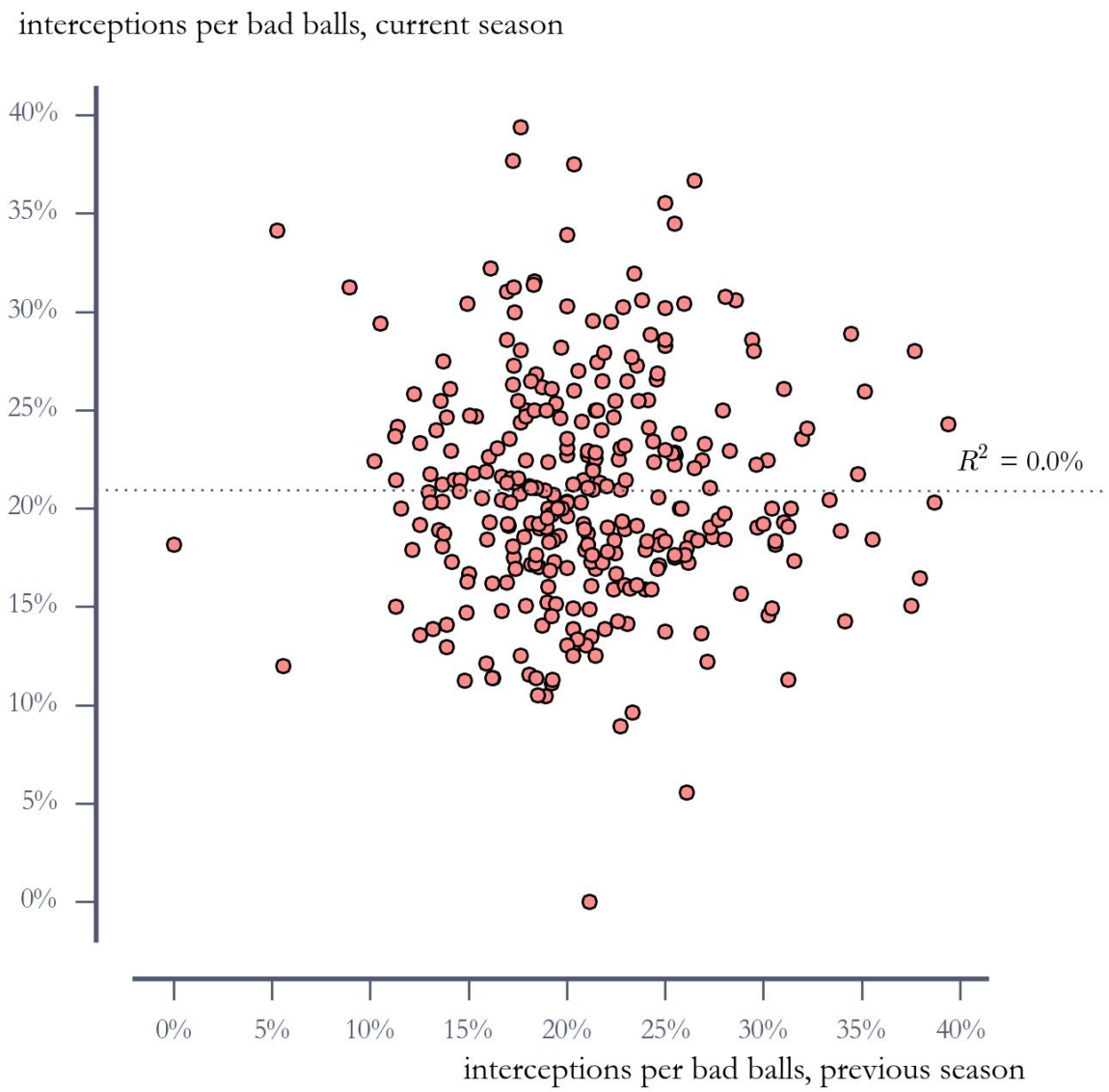
The idea with passes defended is that a certain fraction of these balls will end as interceptions. In an ideal world, this fraction should not be sticky from season to

season. We expect strong regression to the mean. This is Bill Connelly's original analysis in college football.

To check this, consider interceptions as a fraction of bad balls. Bad balls are all passes in which a quarterback puts the ball in a dangerous situation. This includes interceptions and passes defended.

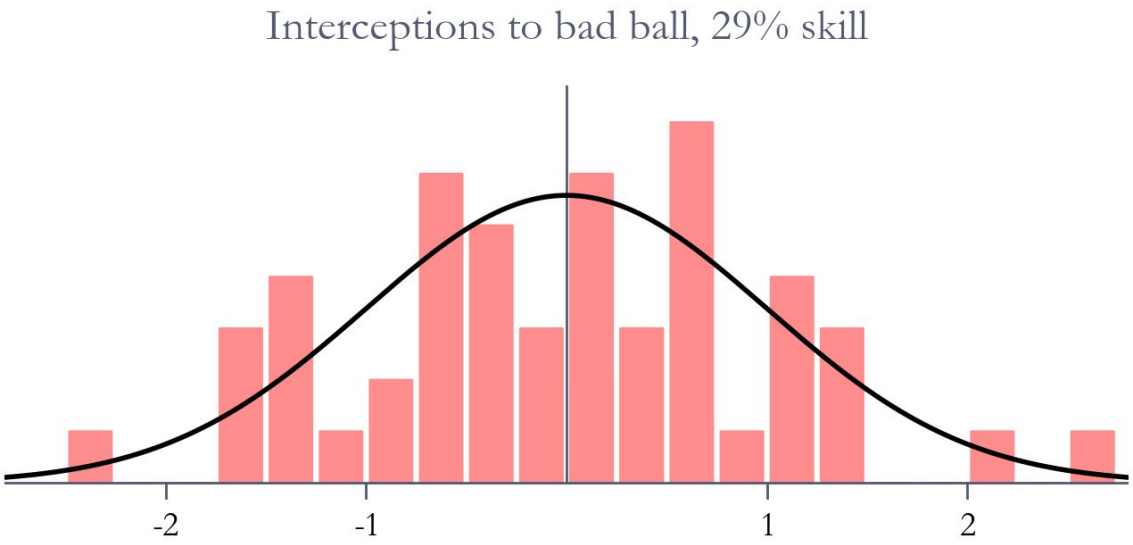
Now consider the fraction of bad balls that end up as interceptions. To calculate this, take interceptions and divide by interceptions plus passes defended. In the NFL from 2014 to 2019, 21.3% of bad balls ended up as interceptions.

This percentage of interceptions to bad balls is not sticky at all. There is zero correlation from season to season. This means we can expect strong regression to the mean from year to year.



We should also check the skill in this rate of interceptions to bad balls. The analysis reveals this rate is 29% skill. The rate of interceptions to bad balls is not all random. Compared to the NFL average of 21.3%, Jameis Winston is still at one extreme with a 27.6% pick to bad ball rate. Aaron Rodgers is at the other extreme with a 14.3% rate, but Tom Brady appears closer to the mean at 19.0%.

In the end, the skill in interceptions per bad balls at 29% is way less than the skill in fumble rate on sacks, which is 49% skill. In addition, with the low level of predictability, the picks to bad ball rate should regress to the mean for quarterbacks.



What happened to John O'Korn? He started the first five games of 2014 at Houston before getting benched. He transferred to Michigan, but he could only win the starting quarterback job when others got hurt.

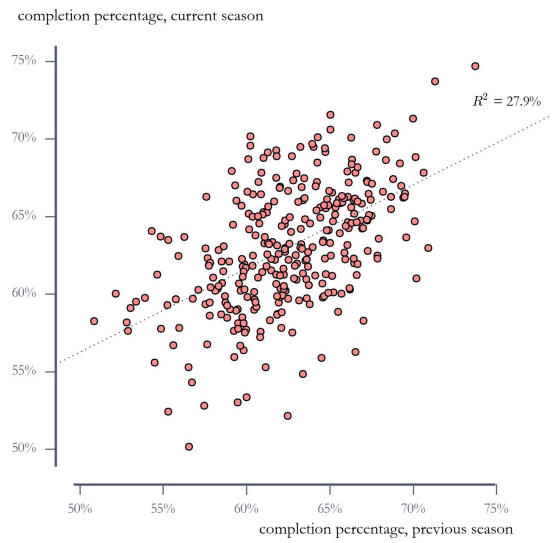
He was a senior in 2017, and one of his starts was against Ohio State. Despite the odds and his poor play, Michigan was in the game. Down 24-20, Michigan got the ball back with less than three minutes to play. O'Korn threw an interception that ended the game.

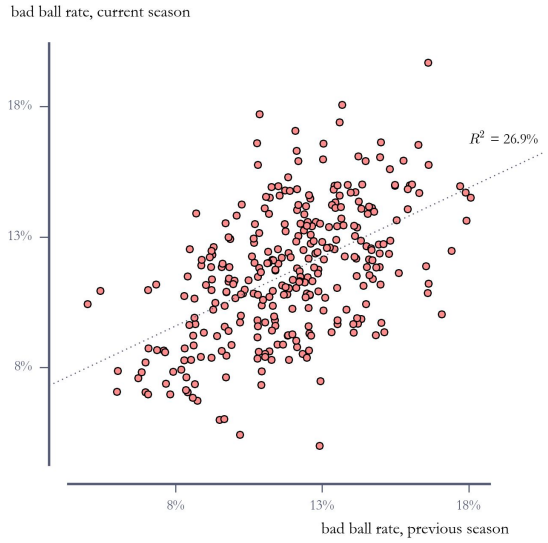
As a freshman, O'Korn had a 2.2% interception rate. But as Connolly noted, that should have been higher based on his passes defended rate. For the remainder of his college career, he had a 5% interception rate. The largest contribution to this poor rate came during his sophomore year at Houston in which he had eight interceptions in 90 pass attempts.

Let's get back to the original goal of predicting interceptions. We could look at passes defended rate and how this predicts interceptions. While this would be a significant improvement, we can do even better.

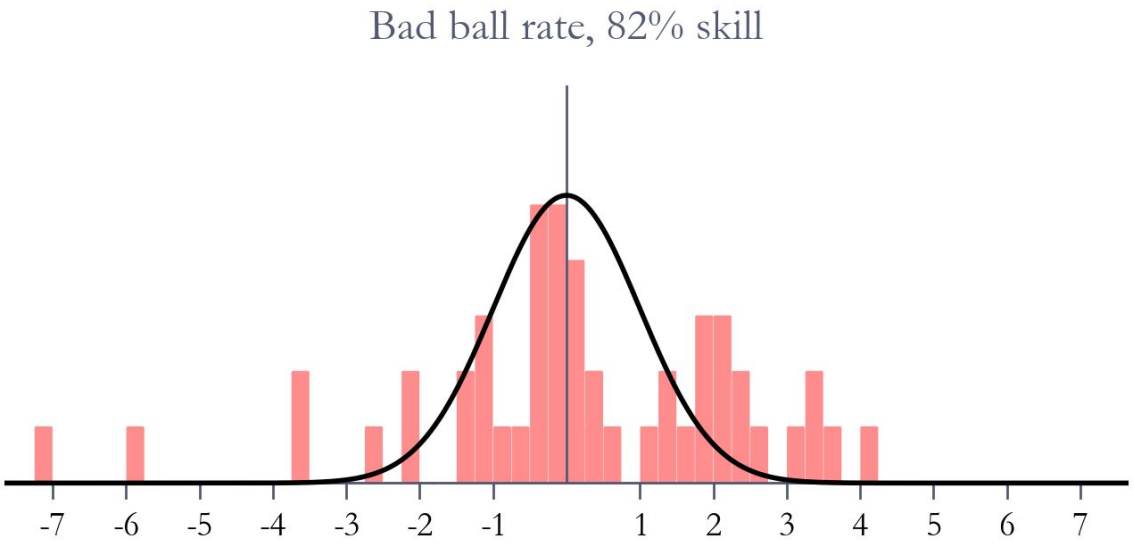
The idea is to know how often a quarterback puts the football in dangerous situations. These balls could end up as passes defended, but they could also end up as interceptions. It makes sense to look at bad ball rate, or interceptions plus passes defended divided by pass attempts. In the NFL the past six seasons, 11.3% of passes end up as bad balls.

Let's check the predictability and skill in bad ball rate. First, last year's bad ball rate for a quarterback explains 27% of the variance in bad ball rate during the current season. Bad ball rate is as sticky as any quarterback statistic gets. Completion percentage had an R-squared value of 28%.



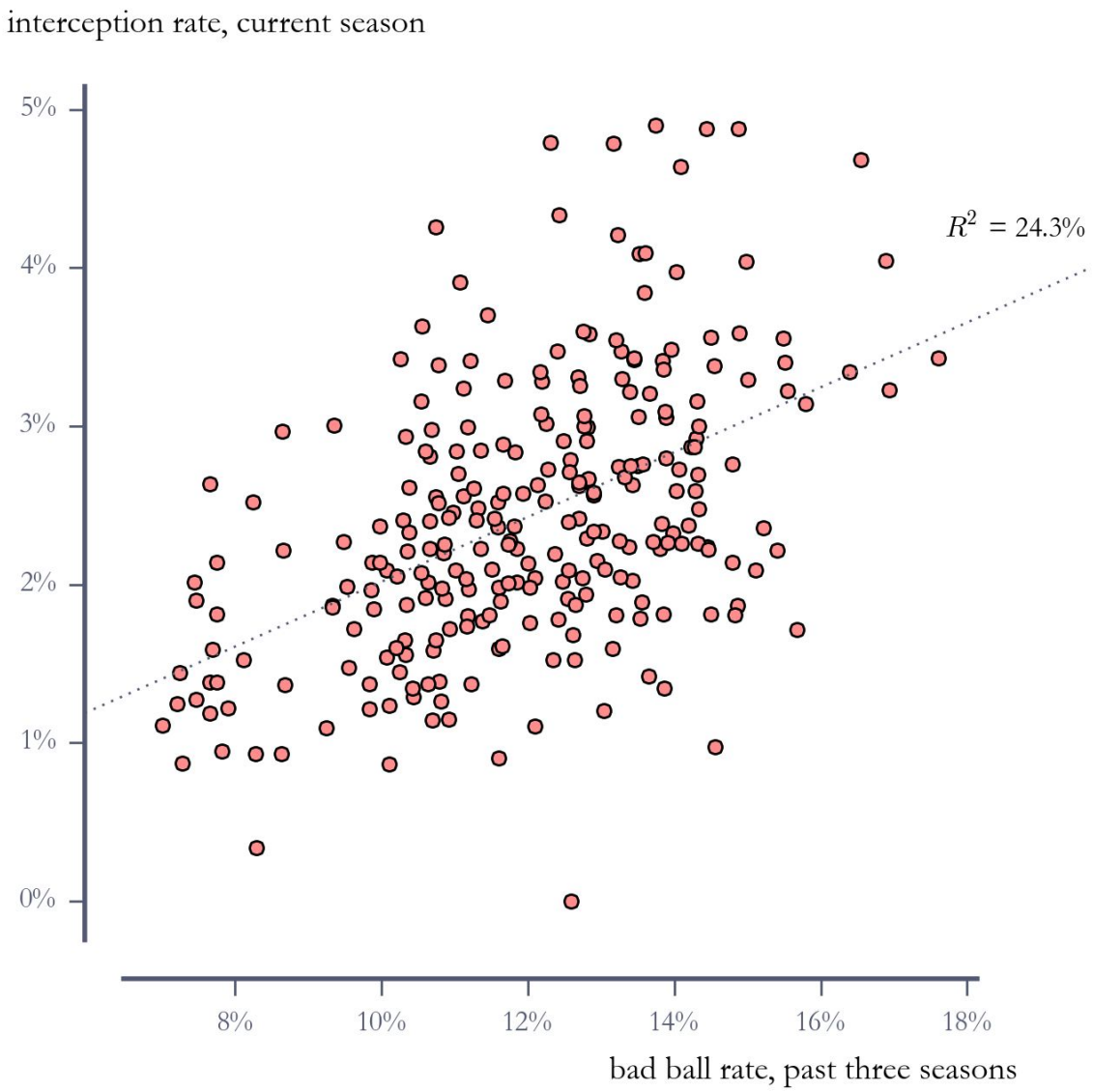


How about the skill in bad ball rate? The analysis shows that bad ball rate is 82% skill. This is better than the 75% skill for passes defended rate, and it's almost as good as the 86% skill for completion percentage.



Let's move onto the most important thing: how well does bad ball rate predict future interception rate? In this analysis, we will not limit ourselves to a single season. With professional athletes, we can look at a number of past seasons to make a prediction.

One year of bad ball rate explains 20% of the variance in interception rate. Two years of bad ball rate does better, as the R-squared value goes up to 23%. The predictability peaks with another year, as three years of bad ball rate explains 24% of the variance in interception rate. With a fourth season of bad ball rate, the predictability declines. Four years of bad ball rate explains 19% of the variance in interception rate.



One explanation for this drop off is coaching. Andy Reid has consistently coached quarterbacks to a below average interception rate. On the other hand, Bruce Arians takes more risks in the passing game. According to Wikipedia, Arian's coaching philosophy is the following:

> No risk it no biscuit, you can't live scared.

Factor in the short life span of coaches, and this could explain the drop off.

As mentioned previously, Tom Brady is one of the best at interception prevention. He has an interception rate of 1.5% from 2017 through 2019. This is excellent, except that his bad ball rate of 8% suggests that his interception rate should be even lower. Now he's under Bruce Arians, which will be one of the best stories in 2020.

QB statistic	R-squared	Skill
Interception rate	6.6%	66%
Completion percentage	27.9%	86%
Passes defended rate	19.6%	75%
Bad ball rate	26.9%	82%
Free throw percentage	69.8%	98%
Three point percentage	14.5%	78%

Let's look at some other interesting quarterbacks for 2020. Since the data show a three year window for bad ball rate is optimal for prediction, the statistics come from the 2017 through 2019 seasons.

Carson Wentz is the Eagles' quarterback, and he laid the foundation for their Super Bowl run in 2017. In his second year, the former #2 overall draft pick played the first 13 games before an injury derailed his season. Nick Foles finished the job as the Eagles won the Super Bowl.

The Eagles' offense hasn't soared as high since. In particular, 2019 was a struggle as Wentz dealt with a number of wide receiver injuries.

The Eagles should fare better in terms of injuries in 2020, but another aspect of regression might hurt the offense. Over the past three seasons, Wentz has had a fantastic 1.5% interception rate.

However, this is deceptive. He has a bad ball rate of 10.7% over the past three seasons, only slightly better than the NFL average of 11.1%. His interception rate should be closer to the NFL average of 2.4%.

In addition, the Eagles had their best year under Wentz in 2017 when they won the Super Bowl. This was actually his worst season for bad ball rate, as 11.8% of his passes ended up in dangerous situations. This rate was worse than his rookie year in 2016. The Eagles never paid for it, as 13.5% of bad balls ended up as interceptions, well below the NFL average of 21.3%. Despite this more advanced analysis, there is still randomness in predicting interceptions.

Wentz's bad ball rate is not awful, but it suggests problems with his accuracy. Sheil Kapadia writes about the NFL for *The Athletic* and has previously covered the Eagles. In his preview of the 2020 Eagles, Kapadia wrote about Wentz "He's never going to be the most accurate quarterback."

Patrick Mahomes is the 24 year old quarterback for the Kansas City Chiefs, and the Super Bowl champion has had all the superlatives thrown at him. Well, those superlatives stopped for a few quarters during the Super Bowl against San Francisco.

Mahomes struggled with two interceptions during the early part of the second half. One of those interceptions went straight into the hands of a defender. On the other

interception, his receiver Tyreek Hill got his hand on the ball. However, the pass was thrown behind the intended target.

In general, Mahomes has been great at interception prevention. He has an interception rate of 1.6%. Based on 1,283 career pass attempts, he is two standard deviations better than NFL average.

But maybe his bad ball rate gave some clue to his subpar Super Bowl performance. Like Carson Wentz, maybe Mahomes has poor underlying statistics in terms of bad ball rate.

No. The underlying numbers for Mahomes are amazing. His bad ball rate has been 7.6%, four standard deviations better than the NFL average of 11.1%. Only Tom Brady and Aaron Rodgers have been better. Mahomes doesn't put the ball in dangerous positions. In addition, he did come back to lead Kansas City to a Super Bowl win over San Francisco. His interception rate could be even better, a scary thought for the rest of the NFL.

We started with a problem: how do you predict interceptions? It wasn't an easy problem to solve. You can't just look at the interception rate the previous year for a quarterback to predict the current season.

However, this wasn't satisfying. Interceptions are critical plays in the game of football. So, instead of thinking about predictability, we started thinking about the skill involved in throwing interceptions. This was an idea from Michael Maubossian in his book *The Success Equation*, and we found that interception rate is 66% skill.

This high level of skill made it worth digging deeper to see if there was a better way to predict interceptions. The answer came from college football analytics. In 2014, Bill

Connolly introduced the idea that a certain fraction of dangerous passes should end up as interceptions. We can tabulate these types of bad balls by looking at the NFL play by play data.

Passes defended is a hidden variable for quarterbacks that helps us predict interceptions. We considered bad ball rate, which is interceptions plus passes defended divided by pass attempts. From season to season, bad ball rate is as sticky as any NFL quarterback statistic.

This analysis showed that interceptions among bad balls are random and unpredictable. But when we take the larger set of bad balls (interceptions and passes defended), it becomes significantly less random and more predictable.

This idea can be applied to other areas of football and basketball. For example, to predict three point shooting percentage in basketball, it might be helpful to include two point jump shot percentage. These mid range shots, while terrible from an expected points perspective, might expand the data set in a useful way.

In football, the take home message is the following: bad ball rate is an important statistic for NFL quarterbacks because it allows for predicting interceptions.