DIRECT: A Two-Level System for Defensive Pass Interference Rooted in Repeatability, Enforceability, Clarity, and Transparency

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Abstract

For this project, we conducted an analysis of predicted catch probabilities to determine suitable rule proposal changes that would help improve the game. We analyzed ∼6,000 catch plays from the sample of 91 games provided as a part of the Big Data Bowl. We built a multinomial logistic regression model to help us predict catch probability statistics if we had altered the predictors we used, like the different pass lengths of each play. By filtering catch probability plays by the type of penalty called, we discovered various insights pertaining to how each penalty was being officiated, most notably the bimodal shape of the defensive pass interference (DPI) distributions. We hypothesized that this was because of differing standards for what a DPI entails. Through a detailed analysis of the data, we propose a novel "two-level" system for DPI which protects the officials on borderline calls:

- "Common Foul" penalty will be defined as a general PI call (holding receiver's arms down, pushing, etc.) where the defender **was** playing the ball and results in a 10-yard penalty.
- "Flagrant Foul" penalty will be defined as a general PI call where the defender clearly **was not** playing the ball and results in a spot foul.

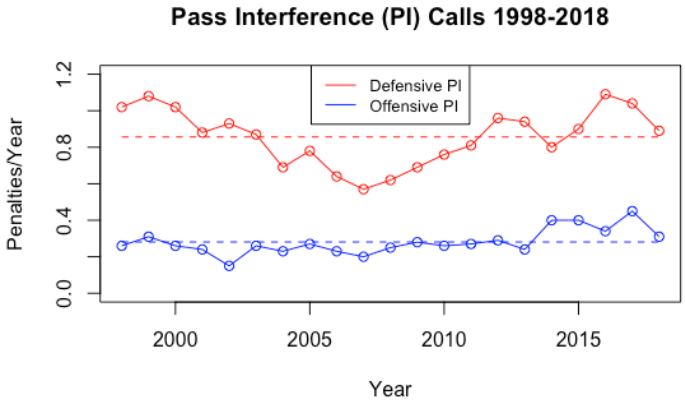
Our models enable us not only to make confident predictions about altering the yard penalties assessed in penalties, but also illuminated various similarities and differences between types of calls that were previously unaccounted for. Through our catch probability statistics, we expect our work to ultimately serve as vital parameters for future work involving understanding the most effective ways to officiate pass interference fairly. Finally, all the code, data, and figures for this project is fully reproducible and accessible at: `https://github.com/pwu97/pass-interference`.

1 INTRODUCTION

In broad terms, pass interference is a penalty in which a player intentionally prevents another player from attempting to catch a pass (see Figure 1b for an example of a correctly called pass interference play) [1]. Pass interference can be called on an offensive player or defensive player, and if a defensive pass interference is called and the offense accepts the penalty, the offense gets the ball at the spot of the penalty (a spot foul) and an automatic first down.

In the following sections, we take a closer look at pass interference. Defensive and offensive pass interference calls have long been controversial calls in the NFL (National Football League). What exactly determines how much contact is too much? Why are penalties called sometimes and not others? Is a spot foul too generous to the offense? In particular, many critics and fans have pointed to the fact that just one defensive pass interference call has the potential to ruin a game where the play clearly was not a defensive penalty at all (offensive player exaggerates contact, defensive player tugging opponent's jersey loosely, etc.). Not only is this idea theoretically supported, it is also historically supported. The New Orleans Saints' Week 16 game against the Pittsburgh Steelers and their conference championship game against the Los Angeles Rams during the 2018-2019 NFL season are two recent examples that come to mind.

Another point of contention on the existing pass interference rules is that it isn't a reviewable call. This means that penalties cannot be reversed, and that coaches cannot challenge an iffy call. Several teams have proposed expanding the use of replay to include penalties such as pass interference. However, not much has been changed, and judgement calls, such as pass interference and holding, have remained unreviewable, likely due to the subjective nature of the call. Yet, through examination of the Canadian Football League (CFL), we notice that the CFL started making pass interference calls challengeable during the 2014 season and continues to do so [2]. In the 2016 season, "coaches challenged 50 calls related to defensive pass interference, and 18 were overturned" in 69 games. We believe that the successful implementation of a review process for interference call would be both beneficial and feasible given the relative similiarities between the NFL and CFL. Furthermore, an overturned call has the potential to drastically affect a game for the better, as we will soon see.



(a) Trends for Defensive and Offensive PI Calls

(b) Correct Defensive PI Call

Figure 1: Defensive and Offensive PI Trends The figure on the left displays the number of defensive and offensive PI calls per year from 1998-2018. The horizontal dashed red line shows an average of about 0.8 DPI calls/year while the dashed blue line shows an average of about 0.3 OPI calls/year. The figure on the right shows a frame of a play that was correctly called a defensive pass interference (i.e. defender was not playing the ball).

Another aspect of the penalty to discuss is its role in the way offenses function. The fact that the offense is rewarded with the ball being placed at the spot of the foul is an incentive to attempt long passes and try to draw a defensive pass interference penalty. In an insightful conversation about this particular call on Reddit, one user asserted: "When throwing the ball in hopes of getting pass interference is part of the game plan, there is something wrong with the rule" [3]. A desperation heave simply shouldn't allow the offense to move forty yards upfield due to minor contact between a wide receiver and safety.

According to Pro Football Reference, defensive pass interference calls were called 1.04 every game, amounting to 18.09 yards per game [4]. While this isn't an enormous amount, the fact that merely one bad defensive pass interference call has the potential to completely shift the balance of a game is not a positive for the game of football. Additionally, with the NFL becoming more and more of a pass-heavy and offensively-minded league, the incidence of defensive pass interference penalties is increasing (see Figure 1a). In an article about a propsed change to the rules regarding pass interference, Mike Florio noted that "Competition Committee chairman Rich McKay said that last year's defensive pass interference calls spiked from a 15-year average of 234 to 303" [5]. When these penalties rise by nearly 30 percent, it becomes even more important to ensure that the rule be modified to reduce the likelihood that these penalties exert unwanted influence on the outcome of games.

Finally, we note that defensive pass interference has recently been brought into the spotlight as a potential rule to change. Before the current 2018-2019 season, the NFL Competition Committee offered a proposal to change the current defensive pass interference to a 15-yard penalty for any interference call that wasn't deemed egregious [6]. However, this proposal did not gain enough votes from NFL owners to pass. In lieu of this rule change, the NFL Competition Committee, in its "2018 Rules Changes and Points of Emphasis," stated that "both offensive and defensive pass interference will also be strictly enforced" this season. We believe that the recency and timeliness of the issue of pass interference calls make it an ideal focal point for this paper.

2 METHODOLOGY

2.1 Data Overview

Our data came from the NFL Big Data Bowl hosted by the NFL Operations staff: `https://github.com/nfl-football-ops/Big-Data-Bowl`. This data was collected through the course of 91 games in the 2017-2018 NFL season, and contains the locations, speeds, and angles of players during each "frame" (a tenth of a second) of a particular play. Thus, because there are a total of 22 players on the field at a given time, there are 22 rows of data corresponding to each frame (excluding the row of data for the football) of a given play. Each play (composed of multiple frames) has about 3,000 rows of data, and each game amounts to nearly 300,000 rows of data. Resultantly, we gained an immense catalog of data corresponding to every play from the sample of 91 games.

For our analysis, we chose to focus on the passing plays because we were specifically interested in proposing a rule change related to pass interference. Additionally, we kept our analysis limited to data related to when the ball was thrown by the quarterback (event is "pass_forward") and when the ball has arrived to its intended receiver (event is "pass_arrived"). We discarded the plays where some event would have altered the ball being thrown to a receiver, and thus never arriving to him (tipped ball, ball thrown away, etc.). This amounted to 6,265 catch plays and essentially limited our dataset to plays where the receiver has a reasonable chance to catch the ball, specifically the type of play that is related to the pass interference penalty. Some catch plays had missing data and so we adjusted our dataset accordingly in those cases.

2.2 Tracking the Moving Parts of a Particular Play

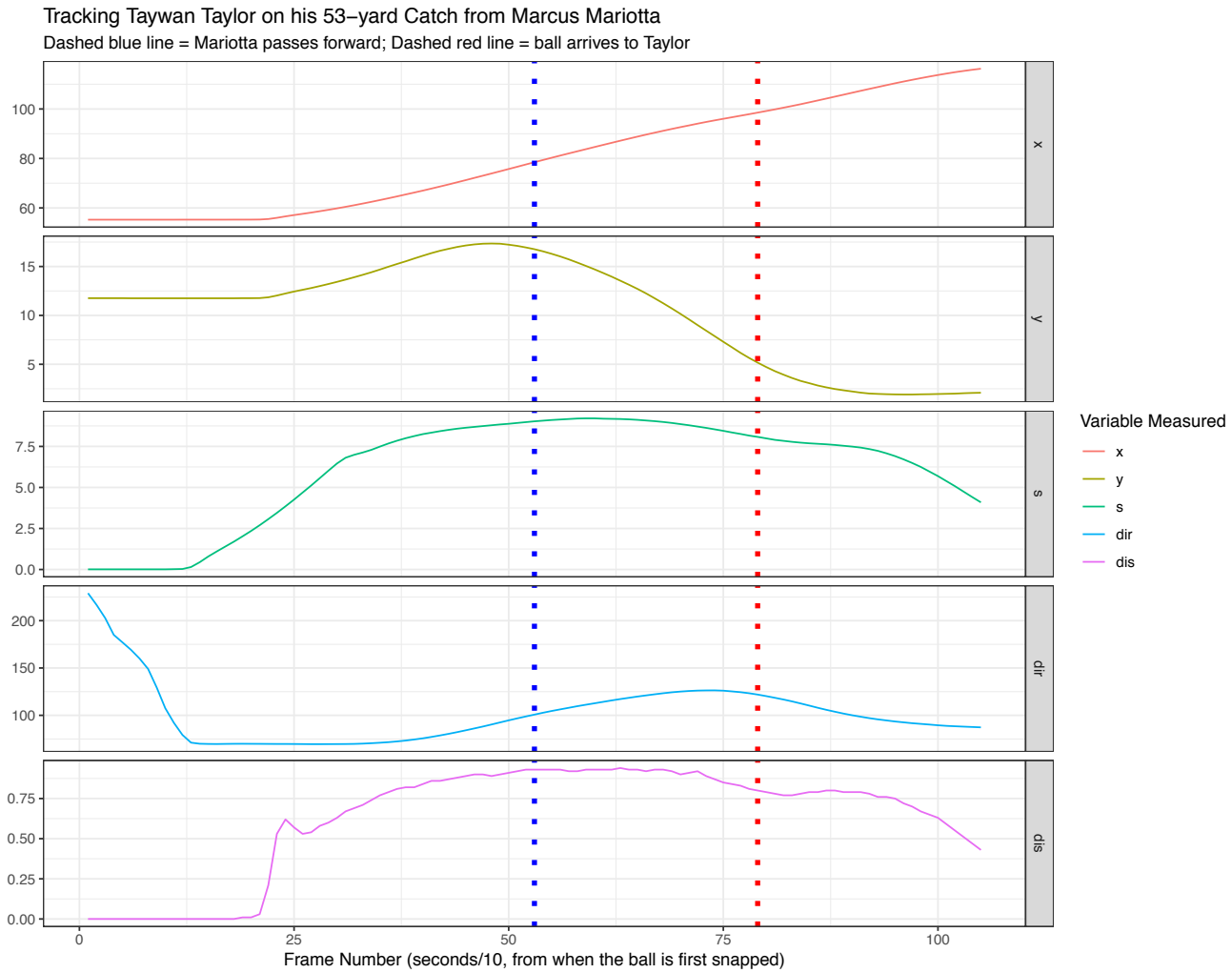


Figure 2: Taywan Taylor Variable Fluctuations on 53-Yard Catch Play. This figure plots the progression of Taywan Taylor's x–y coordinates, speed, displacement, and angle facing on his 53-yard catch from Marcus Mariota. The blue dashed line represents the frame (one-tenth of a second) when Mariota passes forward, and the red dashed line indicates the frame when the ball arrives to Taylor.

When the ball is snapped on a given play, there is a large collection of moving parts in a play: from the pass rushers attempting to gain position to receivers altering their acceleration and angle to separate from their defenders. Figure 2 displays how five variables we tracked in the data fluctuate throughout the duration of a play: the x–y coordinates, displacement from prior frame, speed, and angle facing. In particular, the collection of plots in the figure illustrates how these variables progress throughout a 53-yard pass play from Marcus Mariota to Taywan Taylor. Note that the blue dashed line represents the the frame where Mariota passes forward, and the red dashed line represents the frame where the ball arrives to Taylor. After visualizing this type of data for several players, we attempted to build models that can help us understand pass interference better (more formally the fluctuations between the blue and red dashed lines).

2.3 Looking Into Catch Probability Models and Predictions

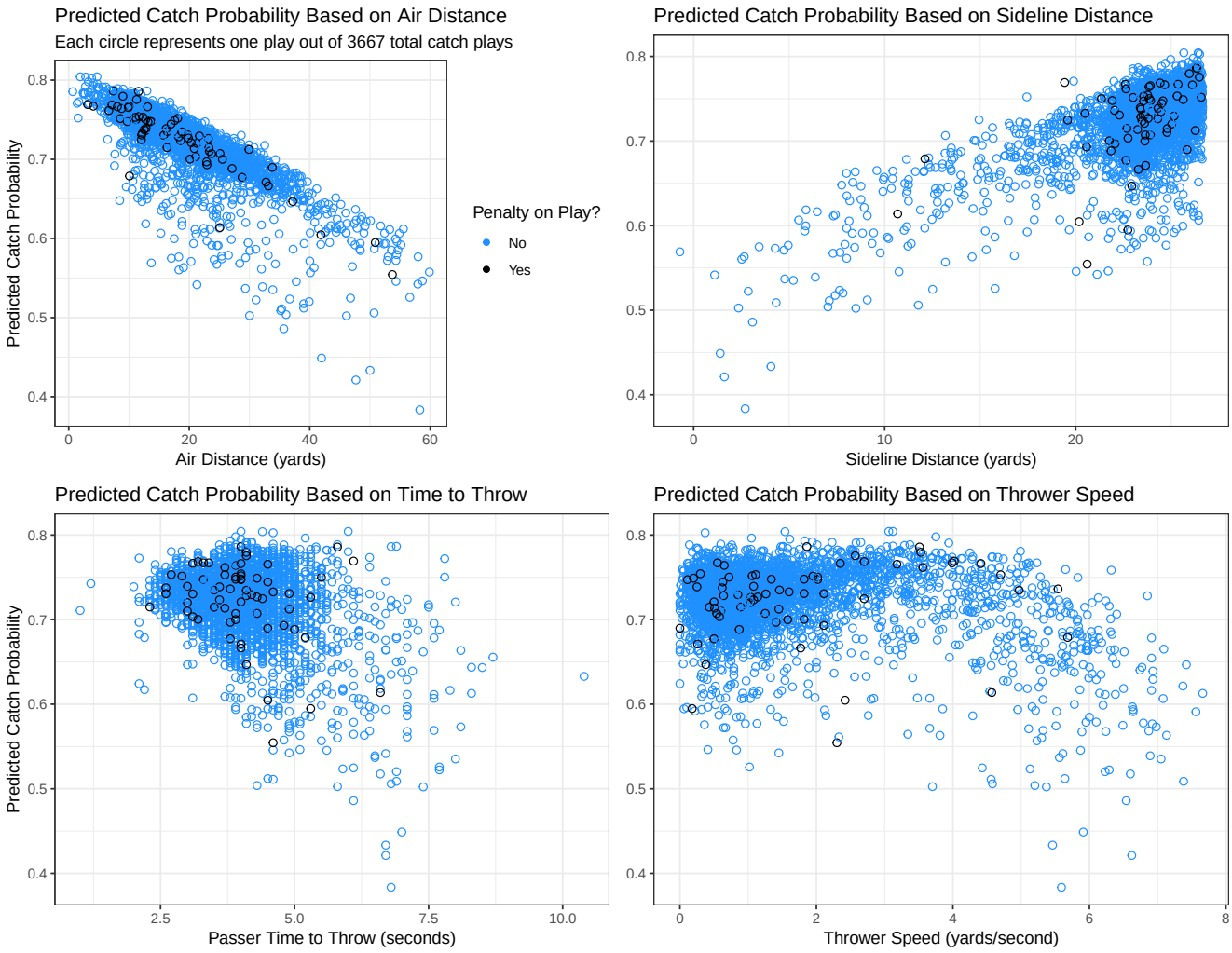


Figure 3: Predicted Catch Probability Against Several Variables. This figure plots the predicted catch probability based on multinomial logistic regression on 3,667 catch plays based on air distance, sideline distance, time to throw, and thrower speed. The blue points indicates no penalty was called on the play, while the black points represent plays where a penalty was called. Plays where the ball did not arrive to the intended receiver were not used in building this model.

In this study, we choose to focus on a few select variables that have shown to be highly correlated with the likelihood a pass is caught: air distance, sideline distance, time to throw, passer speed, and target separation [7]. We fit a multinomial logistic regression model (see Equation 1 below) to the variables, and then looked into how having a penalty called on a play (specifically pass interference) could affect catch probability.

$$Pr(C = 1|\mathbf{x}_i) = \frac{\exp(\beta^T \mathbf{x}_i)}{1 + \exp(\beta^T \mathbf{x}_i)} \tag{1}$$

In this model, C is the dependent random variable of our model representing whether or not a catch was made. $\mathbf{x}_i$ represents the vector with the independent variables listed above. β includes the weights for each independent variable and is estimated using the corresponding data.

Proposing a new rule to be implemented should not only require intuitive sense from a pure game

standpoint, but should have sensible data supporting why the new rule should be imposed. Determining how pass interference calls could affect catch probability is the path we will take in assessing whether these new rules should be implemented. In Figure 3 above, we plot the catch probabilities for the 3,667 total catch plays in the data against several variables used in the model. We highlight the catch plays where a penalty was called with black circles to explore these specific calls more closely.

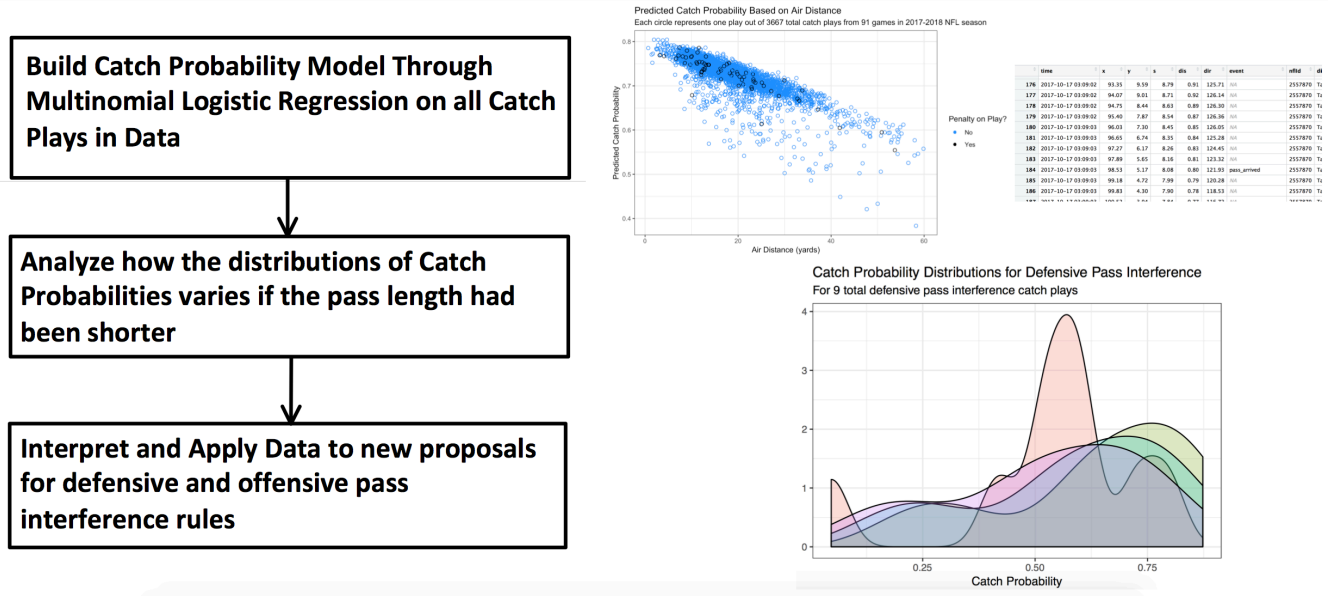


Figure 4: Comprehensive Pipeline to Assess Proposed Rule Changes This diagram represents the intended path that this project will take. First, we will build a multinomial logistic regression model to predict catch play probability. Then, we will alter the pass length of these plays to analyze how the distributions may change. Finally, we will interpret the data in its entirety to assess the pros and cons of several rule changes we have proposed regarding pass interference plays.

Breaking down the complex system of a play further, we collected data relevant to a catch when the ball is thrown forward and when the ball arrives to the receiver. After building a suitable catch probability model through multinomial logistic regression on our dataset of catch plays, we analyzed how varying the pass lengths affects the distribution of catch probabilities. This is vital to understanding pass interference because a large portion of the call is interpreting whether the receiver would have caught the ball "barring significant hindrance". Probability gives us a more transparent lens into tackling this problem. After interpreting and analyzing the data, we applied our insights to new proposals for defensive and offensive pass interference rules.

Furthermore, we took a macro-perspective and visualized the data we obtained from our model to consider how our rule proposals would change the game in the future. Figure 4 summarizes the intended pipeline for this project.

3 RULE CHANGES PROPOSED

3.1 Clarifying the Pass Interference Call

We propose that the NFL states *exactly* what it means for a play to be ruled a pass interference. According to Rule 8–Section 5–Article 1 from the NFL Rulebook, it is pass interference by either team when any act by a player more than one yard beyond the line of scrimmage significantly hinders an eligible player's opportunity to catch the ball [8]. We hypothesize the reason why pass interference calls are very

controversial in today's game is because there is no strict definition of specific actions that can be used as a standard in judging this call, specifically the ones explained in Article 2 and 3 on pass interference. We propose re-writing the rulebook to clarify what it means for a play to be deemed pass interference with increased transparency.

To do this, we first draw motivation from the roots of why the pass interference call was first implemented. As it stands today, a defensive pass interference is a spot foul to equalize the situations where the receiver would have caught the ball barring the "significant hindrance" from the defensive player. The premise makes logical sense, and this rule is not what stirs controversy among players, fans, and coaches alike. The widespread problem is the fact that there are a substantial amount of plays where the defensive pass interference was not "egregious" or "flagrant" enough to be the cause of the failed catch. As it stands now, the defensive pass interference call is putting onus on a referee to conclude in a split second whether contact made by a defensive player "significantly hinders" an offensive player enough to account for a failed catch.

Figure 5: Joe Haden's Minimal Contact Called for DPI. This photo displays a frame during the Pittsburgh Steelers vs. New Orleans Saints game on December 23, 2018 where Joe Haden has one hand on Alvin Kamara's back and does not restrict Kamara's movement to the point where he would have caught the pass had Haden made no contact with him. Yet, defensive pass interference was called on this play on Haden and resulted in essentially a guaranteed touchdown for the Saints and momentum going forwards in the game.

As a concrete example, in a game between the Pittsburgh Steelers and New Orleans Saints on December 23, 2018, Joe Haden was called for defensive pass interference on Alvin Kamara when upon further review there was minimal contact from Haden throughout the whole play. Yet, this one questionable play shifted the balance of the game entirely by enabling the Saints to advance nearly 40 yards to the 1-yard line. Bad calls are inevitable in the game of football, but when light touching results in a nearly 40 yard penalty and essentially a guaranteed touchdown, there must be some form of checks and balances to ensure that plays like this do not happen (be it replay, enabling challenges on pass interference, etc.). As Joe

Haden astutely points out, "it sucks because those plays are so big, and they are weighted differently." Why can one bad call completely shift the balance of the game unfairly? In the next section, we propose potential rule changes that can remedy this inconsistency in pass interference calls.

3.2 Two Levels of Defensive Pass Interference (DPI) Calls

Our proposal is to define two levels of defensive pass interference. To draw a note from the NBA (National Basketball Association), we define the first level of a DPI as a 10-yard penalty ("common foul"), and the second level of a DPI as a spot foul ("flagrant foul"). If the spot foul penalty is less than 10 yards, the "flagrant foul" penalty will be 10 yards. We will keep the current definition that a DPI is called when "any act...significantly hinders an eligible player's opportunity to catch the ball." In real time, it is impossible for a referee to keep track of hand touching, incidental contact, jersey grabbing, etc., and so we stay with the referee making this particular judgment call. However, we protect the referee by installing two levels of a DPI so as to not completely shift the balance of the game because of a particular DPI called by a referee that he/she did not have full conviction on.

3.2.1 First Level of DPI: "Common Foul" = 10-Yard Penalty

In loose terms, we will define first level of a DPI to be a general PI call (defender holds the receiver's arms down, tackles the receiver before the ball has arrived, etc.) where the defender plays the ball. In more specific terms, we first define a general PI call as (b)-(g) from the "Prohibited Acts by Both Teams While the Ball is in the Air" under Rule 8–Section 5–Article 2 of the NFL Rulebook. The other component is where the defender attempts to make a play on the ball, as opposed to the receiver. To summarize the relevant rules, (b) involves playing through the back of an opponent, (c) involves grabbing an opponent's arm to restrict movement, (d) involves extending arm across body of opponent, (e) involves cutting off the path of opponent, (f) involves hooking an opponent, and (g) involves initiating contact with an opponent by shoving or pushing off. In other words, these are actions that referees deemed significantly hindered a catch, but where the defender can be reasonably expected to have been playing the ball. Note that we excluded (a), which covers contact by a player not playing the ball.

3.2.2 Second Level of DPI: "Flagrant Foul" = Spot Foul Penalty

We will define the second level of a DPI call to be a general PI call where the defender was not playing the ball. In more specific terms, the first component of the second level of a DPI will entail a general PI call: (a)-(g) from the "Prohibited Acts by Both Teams While the Ball is in the Air" under Rule 8–Section 5–Article 2 of the NFL Rulebook (as detailed above). Here we include (a). The other component is that the defender doesn't make a play on the ball. In other words, these are actions that the referees deemed significantly hindered a catch, and where the defender did not attempt to make a play on the ball.

3.3 Reviewable and Challengable Pass Interference Calls

In order to enforce the standards of the two-level system explained in Section 3.2, we propose using either replay only or challenge flags for replay.

In using replay only, we state that any defensive pass interference play that results in greater than 10 yards will be automatically reviewed. On the field, the call will be treated as a "flagrant foul" version of a DPI. The referees will review the play by assessing whether the defender made a play on the ball (as

opposed to the receiver) to determine whether or not to downgrade the DPI to a "common foul" and a 10-yard penalty or keep the "flagrant foul" ruling on the field and a spot foul penalty.

In using challenge flags for replay to enforce the two-level system, coaches can challenge any defensive pass interference plays (like any other challengeable play) and the referees will judge the play like they did in the "replay only" method.

4 RESULTS

4.1 Should We Impose Two Levels of a DPI?

Our proposal outlined in Section 3.2 was to impose two levels of defensive pass interference. To recap, we proposed that referees continue to judge catch plays based on whether the defender "significantly hinders" a receiver's ability to catch the ball, but we institute two levels of defensive pass interference to protect the officials: one for "common fouls" which result in a 10-yard penalty, and one for "flagrant fouls" which result in a spot foul.

Using our model outlined in Section 2, specifically in Section 2.3, we attempted to understand how the distribution of catch probabilities would change had we altered the passing distance of multiple catch plays. Figure 6 shows how the distribution of catch probabilities would change had we imposed a 10-yard penalty, 15-yard penalty, 20-yard penalty, or spot-foul penalty on any given subset of catch plays. To clarify, the 10-yard penalty distribution shows the catch probability distribution if we had altered every spot foul penalty to a 10-yard penalty. The top left plot of Figure 3 shows the subset for all catch plays greater than 10 yards in our dataset (Figure 6a); the top right shows those for defensive pass interference (Figure 6b); the bottom left shows those for offensive pass interference (Figure 6c); and the bottom right shows those for the rest of the penalties called on catch plays (Figure 6d).

In Figure 6(a), the top left plot of Figure 6, all four of the distributions are bimodal distributions. The natural explanation for this is that catch plays can be thought of as following an all-or-nothing rule. Receivers usually compete for every ball to the fullest, so balls are usually either certainly able to be caught (higher probability) or very improbable to be caught (lower probability). The spot foul distribution appears to be nestled between the 15-yard and 20-yard penalty distributions (slightly leaning towards the 15-yard distribution), lending more evidence to why some version of a rule change involving 10+ yard penalties may be a step in the right direction for the NFL.

In Figure 6(b), we have a noisy plot as there were only 9 defensive pass interference plays in our dataset of catch plays, but portray meaningful insights into why some aspect of the spot foul should be kept. The bimodal nature of the spot foul distribution is what lends support to a two level penalty for a DPI: the leftmost peak represents the "flagrant foul" (spot foul) at around a 57% catch probability while the rightmost peak represents the "common foul" (10-yard penalty) at around a 75% catch probability. Notice that we would expect most of the plays to still be spot fouls if we implemented the two-level system because they have to be egregious enough for the referee to deem that there was "significant hindrance" on the defender's part. The catch probability at the leftmost peak is lower than the center of the distribution if the spot foul had been a 20-yard penalty (purple distribution), which supports the notion that a spot foul does serve its purpose when protecting the receivers on plays involving balls they would have caught without "significant hindrance" from defenders. Because the 10-yard penalty and rightmost peak of the spot foul seem to align at the 75% catch probability mark, we believe a 10-yard penalty for the first level of a DPI may be more appropriate than the typical 15-yard penalty. In college, all DPI calls are a 15-yard penalty, and so a 10-yard penalty for the first level penalty in this two-level system captures the essence of a "common foul" better through this precedent set by the NCAA [9].

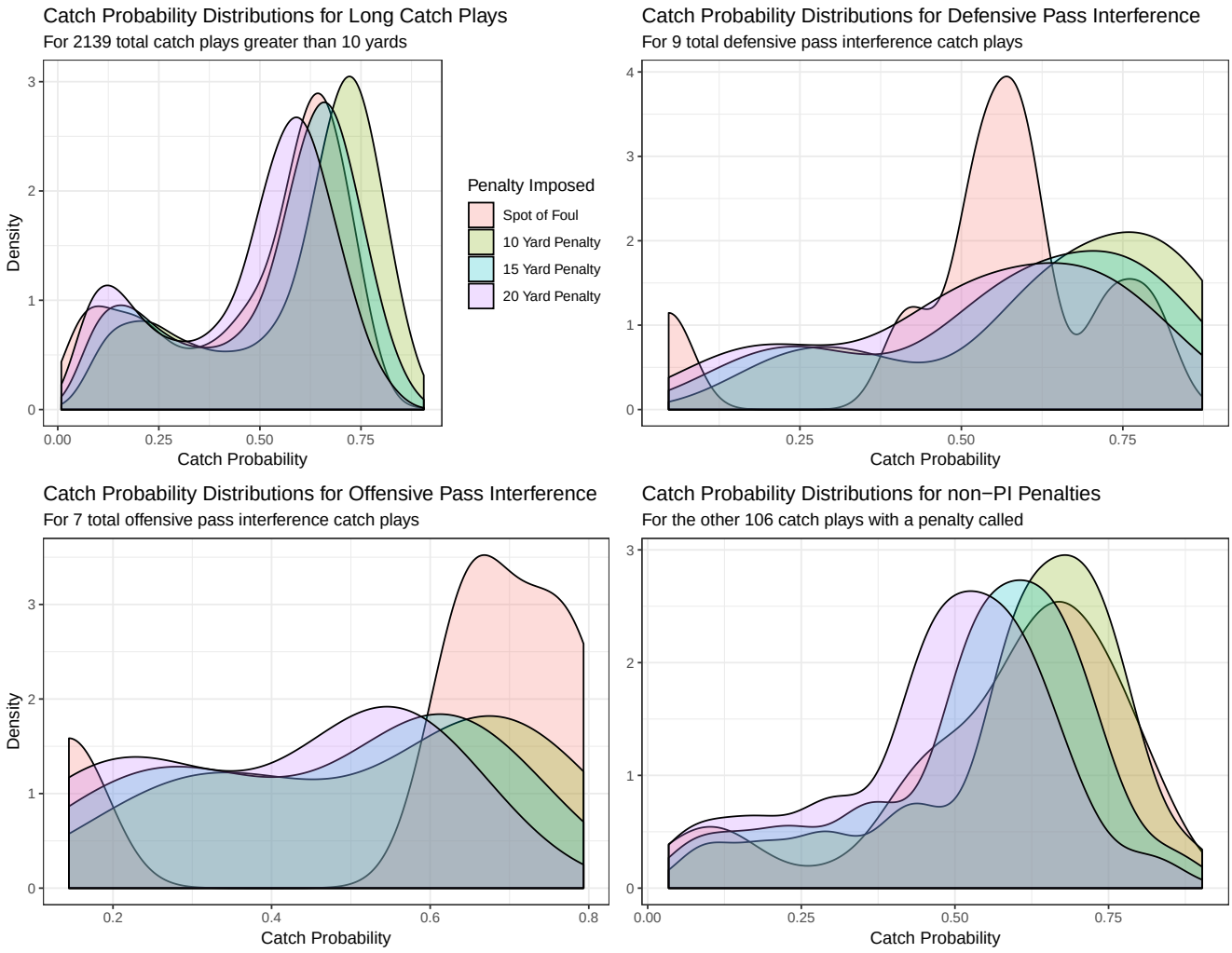


Figure 6: Predicted Catch Probability Distributions This collections of plots shows the predicted catch probability distributions under a variety of different officiating scenarios: spot foul, 10-yard penalty, 15-yard penalty, and 20-yard penalty. As an example, the green density plot shows the distribution of catch probabilities had every spot foul been called a 10-yard penalty. The top left plot shows the distributions for all catch plays over 10 yards, the top right shows them for DPI calls, the bottom left shows them for OPI, and the bottom right shows them for the rest of the penalties.

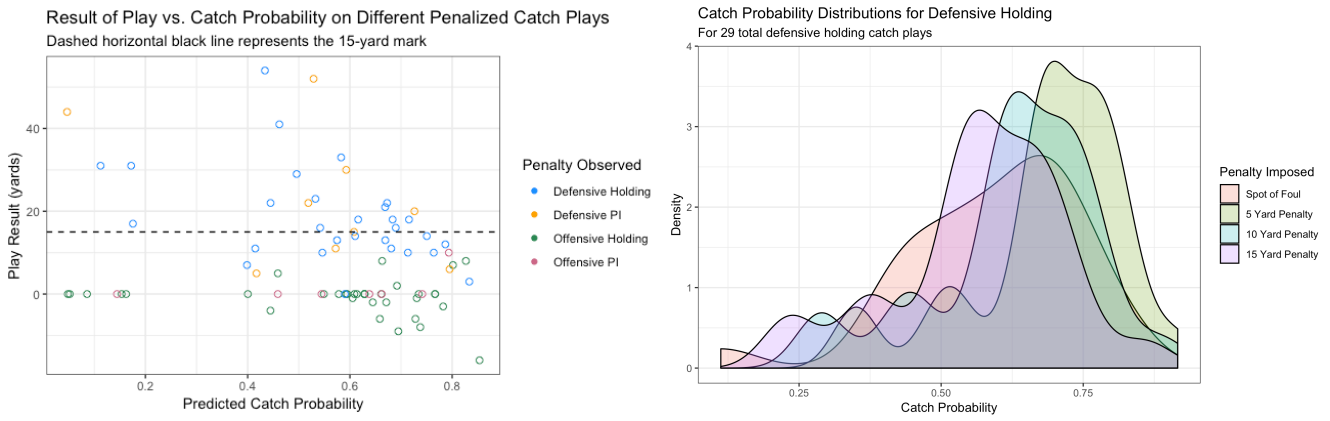
In Figure 6(c), we see that the spot foul distribution is roughly centered around a 66% catch probability, where the 10-yard (68%) and 15-yard penalties (60%) are also centered. This visualization indicates a 10-yard penalty for offensive pass interference seems fair on the surface. In Figure 6(d), we see that the spot fouls and 10-yard penalty distribution are both roughly centered around a 69% catch probability for non-PI penalty plays.

4.2 Should We Cap Defensive Pass Interference?

There are many commentators and sport personalities such as Mike Pereira, former NFL vice president of officiating, who are in favor of a 15-yard cap on defensive pass interference. We believe that although our data and models support a penalty of about 10–15 yards to be a happy medium for defensive pass interference, instilling a hard cap on a the call will not solve the problems related to the call. The reason for this is that the root of the issue lies within the enforcement and clarity of the DPI call. Changing

a specific penalty is not the fix, but rather a halfhearted attempt to make the game fairer by salvaging incorrectly called penalties that happen quite frequently. We believe the best way to address this issue is to enforce two levels of a DPI as discussed in Section 3.2 and 3.3: one for "common fouls" and "flagrant fouls". The second level of a DPI will result in a spot foul and be enforced exclusively in situations where the ball would have been caught barring "significant contact" from defenders (a general PI call) and where the defender was not playing the ball. The first level of a DPI will be a 10-yard penalty imposed where, upon replay, the general PI call involved the defender playing the ball (as opposed to the receiver).

4.3 Two-Level System for DPI: Transparent and Data-Driven



(a) Play Result vs. Catch Probability **(b) Defensive Holding Distributions**

Figure 7: Play Result on Catch Plays and Defensive Holding Catch Probability Distributions The left plot shows the predicted catch probability for catch plays against the result of plays (in yards) for defensive holding, defensive pass interference, offensive holding, and offensive pass interference. The plot on the right shows the distribution of defensive holding under spot foul, 10-yard penalties, 15-yard penalties, and 20-yard penalties. We note the similarity of defensive holding to the "common foul" version of our proposed two-level system for DPI.

Figure 7(a) displays the result of plays for four specific penalties against their predicted catch probabilities: defensive and offensive holding and pass interference. The plot shows defensive pass interference ranging from 5 yards to nearly 45 yards. Instilling a cap on DPI would drastically affect catch plays. The intention of the cap on the surface appears to be well-intentioned, but upon further examination, it could do more harm than benefit by taking away yards receivers should have earned. This may lead to a whole slew of other possible negative consequences because it never truly addresses the issue of how referees are calling defensive pass interference, but rather attempts to minimize the adverse ramifications of bad calls.

Our two-level system both addresses the nature of how the call is made, but also enforces a standards that can improve transparency of the call going forwards. We protect receivers by ensuring the "spot foul" penalty stays a spot foul. Furthermore, we install a "common foul" version of the penalty that results in a 10-yard penalty. Figure 7(b) shows the distribution of the catch probabilities for the defensive holding call using spot fouls, 10-yard, 15-yard, and 20-yard penalties. Our initial exploration indicates that this first level of the DPI call may be compared to defensive holding, as both distributions are centered around a 65% catch probability at a 10-yard penalty and relate to the "common foul" nature of the foul. By enforcing the standards for these two levels explained in 3.2.1 and 3.2.2, we believe the overall transparency and clarity of this call will improve tremendously.

5 CONCLUSIONS AND FUTURE WORK

In this project, we identified weaknesses in how the pass interference penalty call is presently officiated and proposed ways to remedy the current flaws in today's system. From the tracking data given to us, we identified the catch plays and built a multinomial logistic regression model to predict catch probability based on specific variables provided that have been shown to have the largest effect on a catch being made. By analyzing the distributions of catch probabilities for various penalties, we came up with a two-level system for DPI as being a viable and consistent solution to improving how this particular penalty is judged in today's game. Furthermore, our model was able to calculate a variety of catch probability statistics that can be applied to different officiating rule changes. Ultimately, the data and our models all support a two-level system for defensive pass interference ("flagrant foul" involving a general PI where the defender does not play the ball results in a spot foul; "common foul" involving a general PI where defender plays the ball results in a 10-yard penalty) as an effective way of improving the call.

In the future, we see hand-touching and light touching between players as the next area data can be collected to improve pass interference calls. In particular, pairing this data with speed, displacement, and acceleration may prove to be an effective way to better understand how likely it was for the receiver to catch a pass barring "significant hindrance" from a defender, or how much the defender affected the receiver's ability to catch the pass. Most importantly, we aim to use our results to advocate for additional studies to understand the receiver-defender dynamic and to further hone the rules to make penalties fair for both the offense and defense. We plan to collaborate with the Amazon AWS team and develop models and algorithms that detail more extensive catch probability models. Correspondingly, we will be able to push our understanding and intuition of catch probability statistics to new levels.

Finally, all the code, data, and figures for this project is fully reproducible and available in this repository: `https://github.com/pwu97/pass-interference`.

References

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