Reducing Concussion Rates on Punts by Incentivizing Fewer Punt Returns

NFL Punt Analytics Competition

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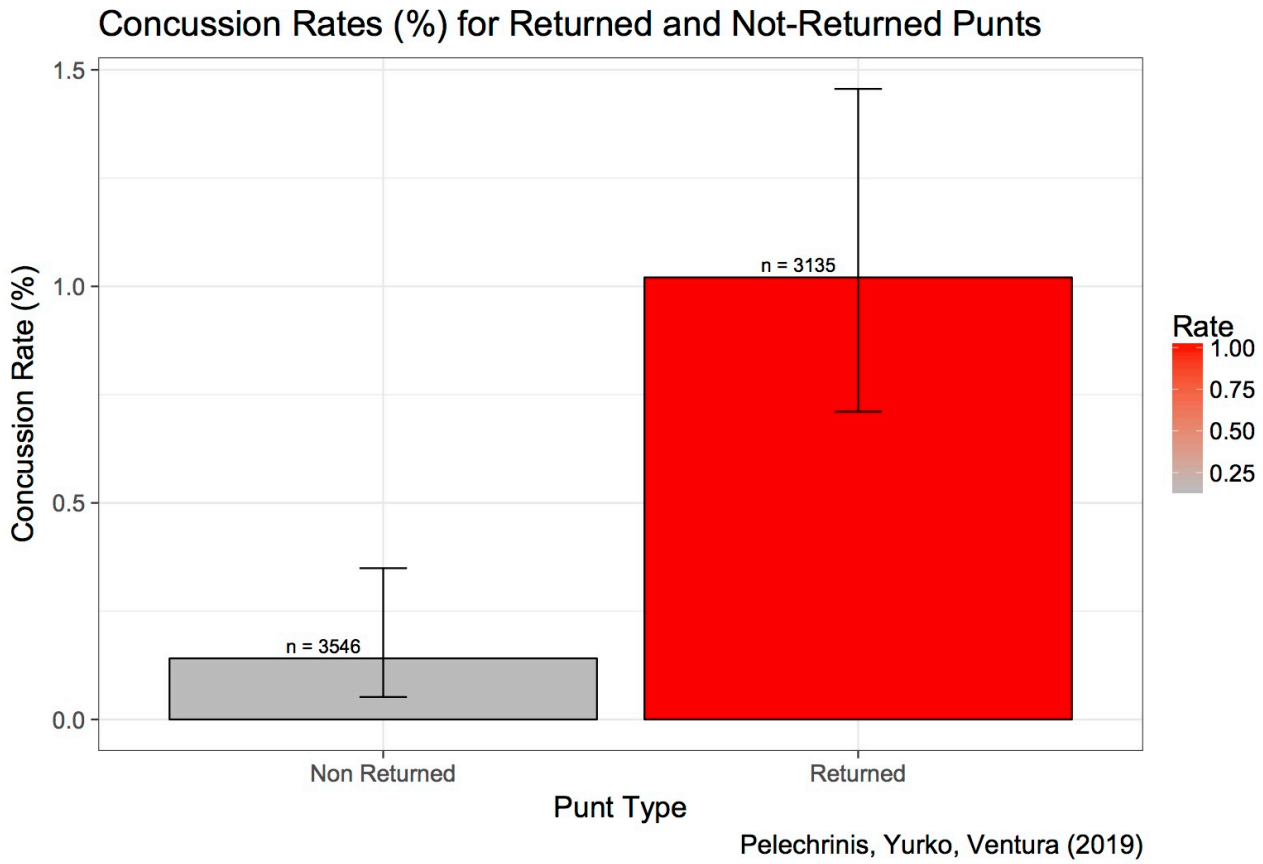
Summary: Fewer Punt Returns $\rightarrow$ Fewer Concussions

1. Our Proposed Rule Changes
2. Analyzing Concussion Rates on Punts
3. Impact of Rule Changes on Win Probability
4. Impact of Rule Changes on Concussion Rates
5. Discussion
6. Appendix

Our Proposed Rule Changes

Concussion Rates are Significantly Higher on Returned Punts



The concussion rate is **seven times higher** on returned punts as compared to non-returned punts

The easiest way to reduce the number of concussions sustained on punts is to **reduce the number of punts that are returned**

Our Proposed Rule Changes

Our two proposed rule changes are:

1. If the return team successfully completes a “Fair Catch”, the ball is placed 5 yards closer to the kicking team’s end zone.

2. If the kicking team punts the ball out-of-bounds on a fly, the ball is placed 5 yards closer to the return team’s end zone (or half the distance to the goal if inside the 10 yard line).

These rules incentivize both teams to behave in ways that will reduce the number of returned punts.

Summary: How Our Proposals Reduce Concussion Rates

We provide data-driven evidence for each of the following:

1. Almost all concussions on punts occur on returned punts

2. Concussions are less likely on punts closer to the sideline

3. The punting team has incentive to punt the ball out-of-bounds

4. The return team has incentive to call for a fair catch

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2. **Concussions are less likely on punts closer to the sideline**
   - We show that the probability of a concussion being sustained on a play decreases as punts are received closer to the sideline

3. **The punting team has incentive to punt the ball out-of-bounds**
   - We show that the punting team gains win probability added from punting the ball out-of-bounds under rule #2
   - More punts out-of-bounds $\rightarrow$ fewer returns $\rightarrow$ fewer concussions

4. **The return team has incentive to call for a fair catch**
   - We show that the return team gains win probability added from completing a fair catch under rule #1
   - More fair catches $\rightarrow$ fewer punt returns $\rightarrow$ fewer concussions

Benefits of Our Rule Proposals

1. **More punts will be kicked out-of-bounds**
   - Reduces rate of punt returns
   - Fewer punts returns $\rightarrow$ **fewer concussions**

2. **More in-bounds punts will result in fair catches**
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3. **More in-bounds punts will be kicked toward the sideline**
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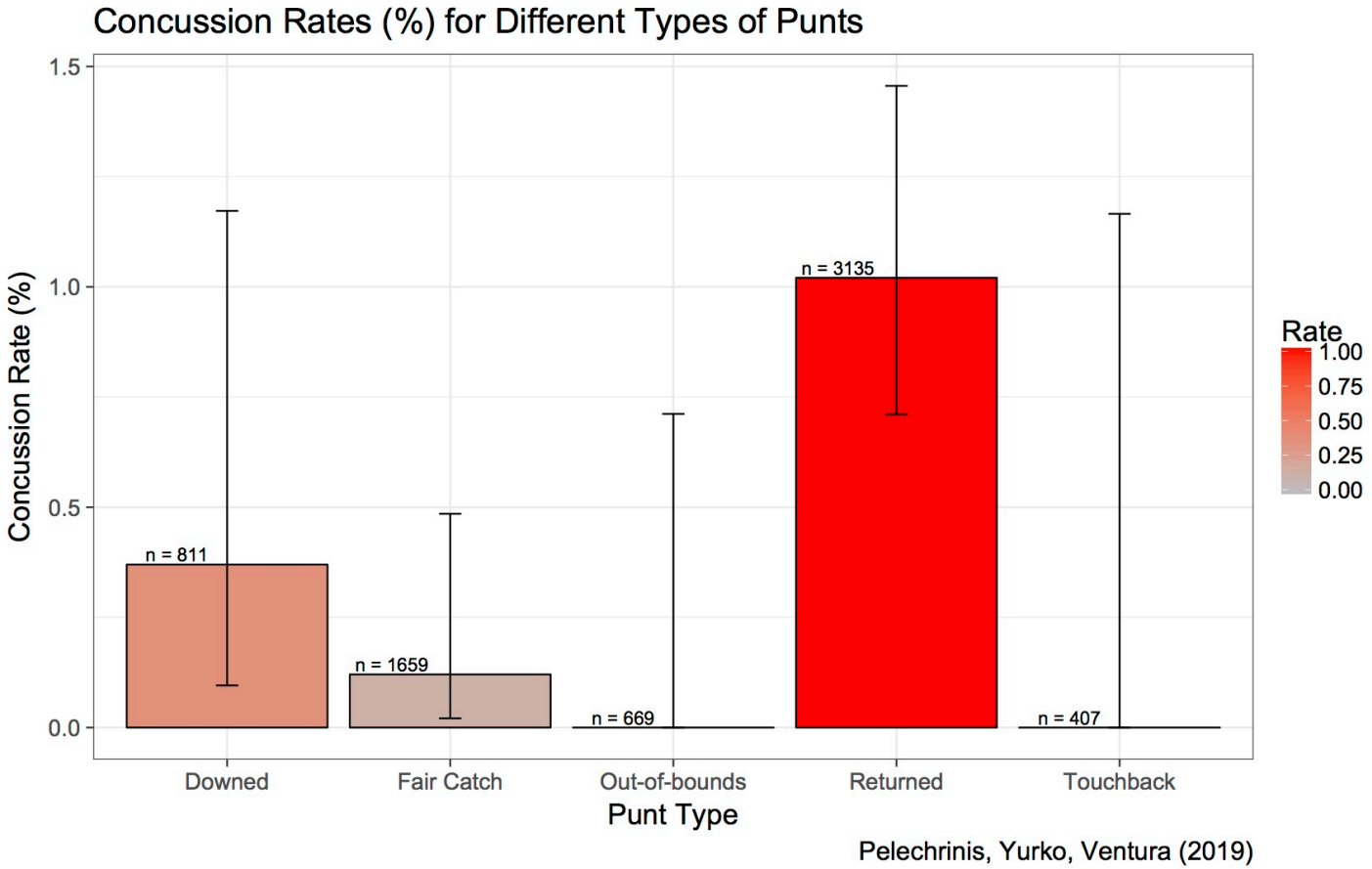
4. **Our proposals are easy to understand and easy to implement**
   - **Minimal effort** required by league officials
   - **Minimal effort** required to educate referees/officials
   - **Minimal effort** required to educate players, coaches, & teams

5. **No fundamental changes to the game required**
   - **No confusing rule changes dictating** how players can tackle
   - **Limits fan confusion** & negative sentiment towards rule changes

Analyzing Concussion Rates on Punts

Concussions on Fair Catches & Out-of-Bounds Punts are Rare

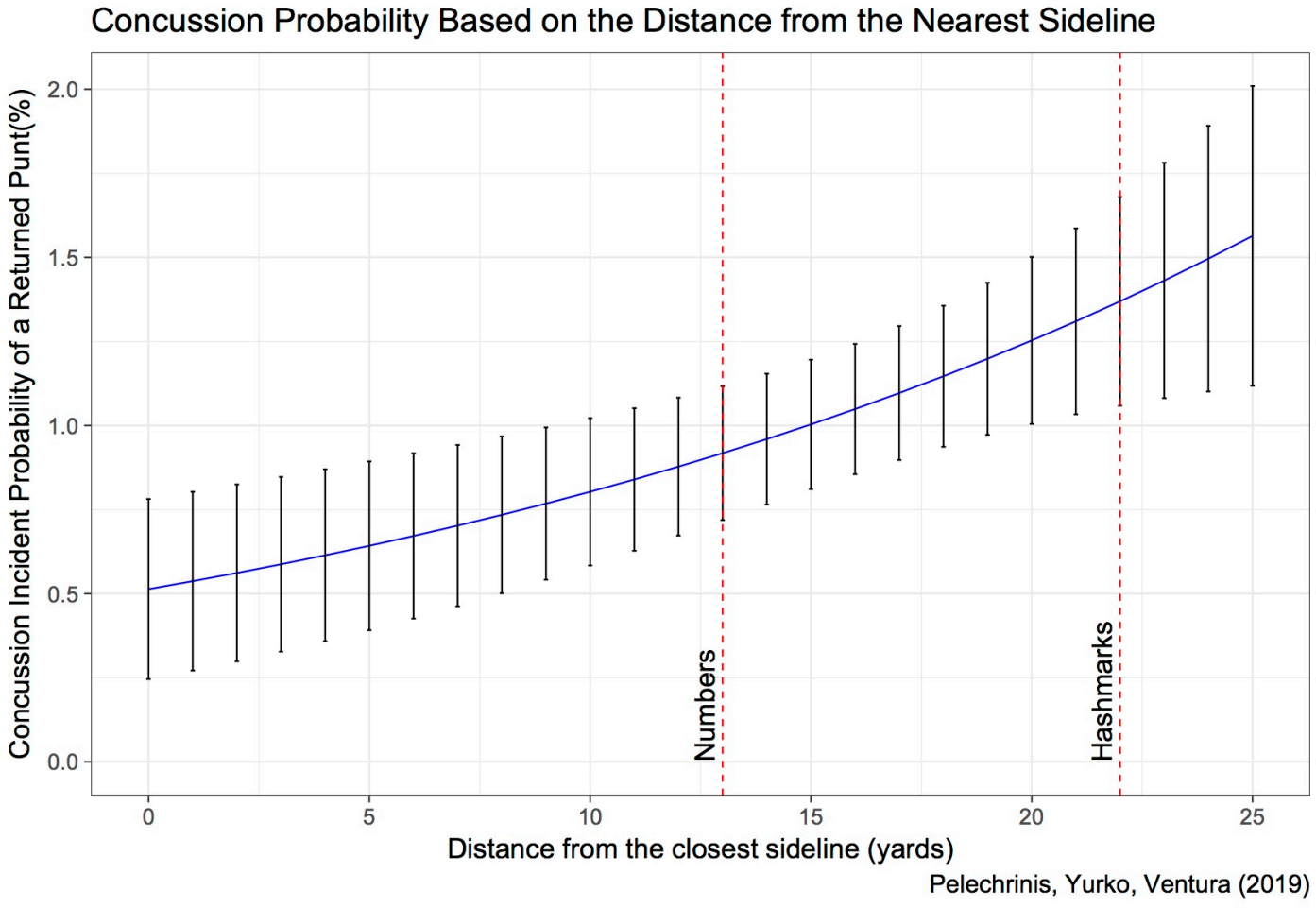


Returned punts have the highest concussion rates.

Fair catches & out-of-bounds punts have low concussion rates.

Concussions sometimes occur on downed punts, which is why we assert that **only punts going out-of-bounds on the fly receive the 5-yard incentive**.

Concussion Likelihood Decreases for Punts Closer to Sideline



Our rule changes **incentivize punts to be kicked towards the sideline**.

These punts are associated with **lower concussion rates** when returned.

Impact of Rule Changes on Win Probability

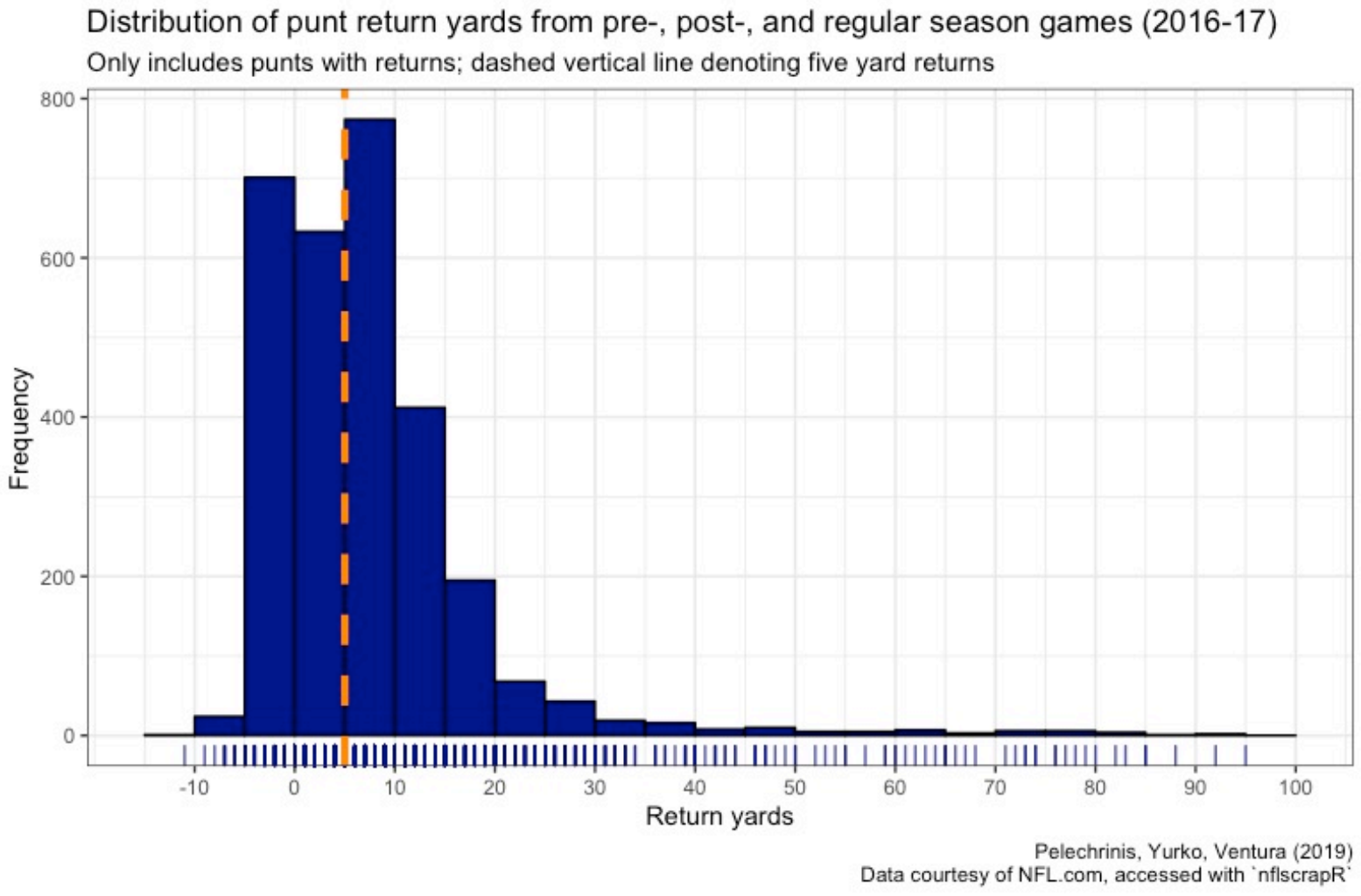
Supplementary Punt Data from NFL Play-By-Play API

The NFL provides an API for accessing play-by-play data for all games dating back to the 2009 season.

We designed the R package NFLSCRAPR for accessing and compiling data from this API.

We analyze the subset of all punt plays in 2016-17 seasons (pre-, post-, regular) from this API.

Most Punt Returns Are For Less Than 5 Yards



Result: 46% of returned punts were returned for 5 yards or less.

Analyzing Punt Results with Win Probability Added

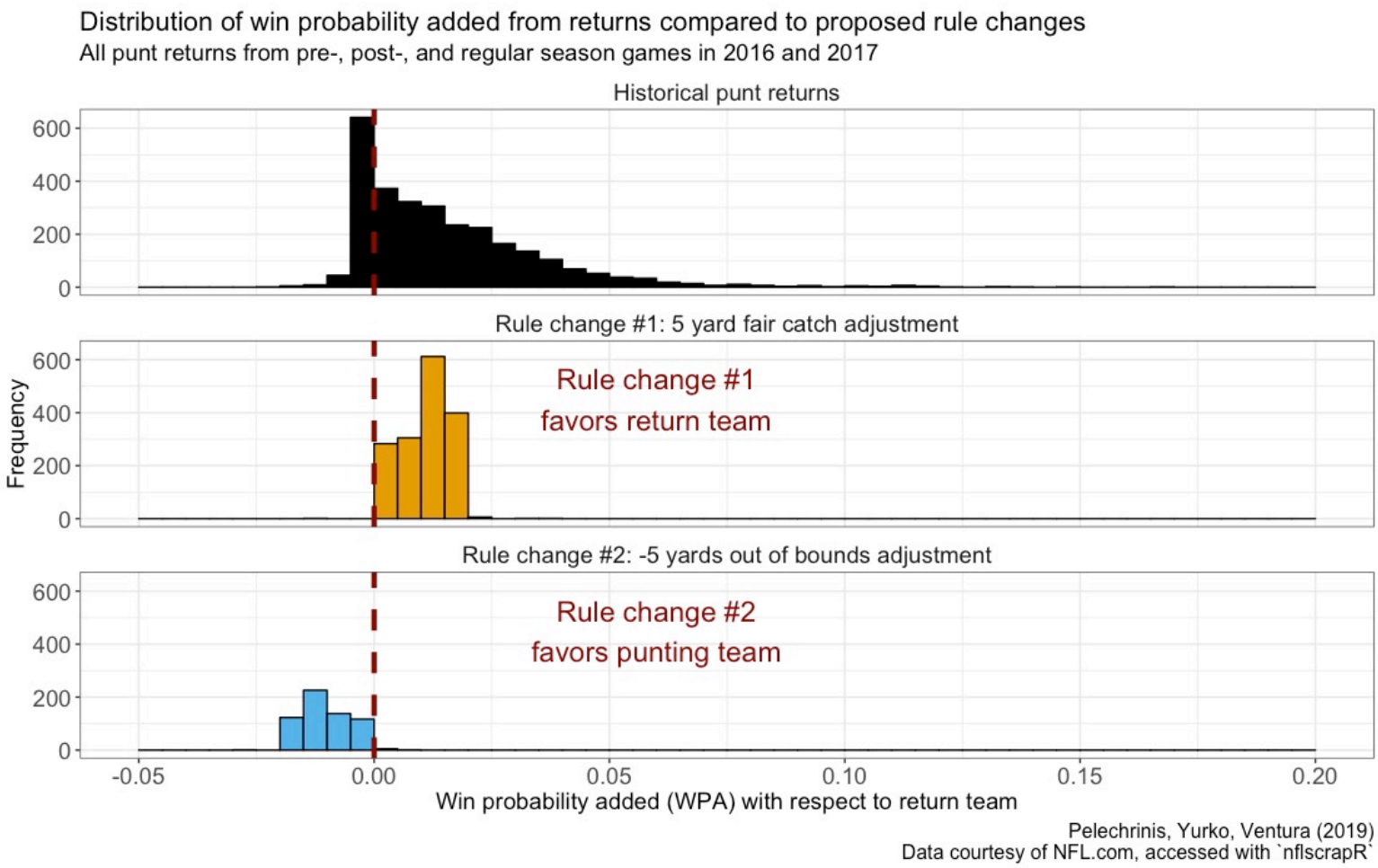
Win probability added (WPA) is the change in a team's probability of winning that can be attributed to a single play

- Ex: A 2-yard run on 3rd-and-1 is worth more according to WPA than a 2-yard run on 2nd-and-10.
- Ex: Cody Parkey's "double-doink" missed field goal vs. the Eagles in the 2019 Wild Card Round was worth -89% in win probability.

We use historical data from the NFL's API to build our WP model

Our model is a generalized additive model that accounts for time remaining, score differential, down, yard line, yards to go, etc

Impact of Rule Changes on Win Probability



Our proposed rule changes incentivize both teams to behave in ways that will **reduce the number of returned punts**.

Fewer punt returns $\rightarrow$ **fewer concussions**

Impact of Rule Changes on Concussion Rates

How Many Concussions Will Be Prevented?

We perform simulations to estimate the impact of our rule changes on **the number of concussions per 1,000 *exposures*** (punt plays)

Our simulations consider ranges of values of two parameters:

(i) r: percentage reduction in returned punts

(ii) s_d: average shift of the punts towards the sideline

For each pair of (r, s_d), we will obtain an estimate for the expected number of concussions per 1,000 exposures (punts)

These 1,000 exposures are categorized in returned-vs-non-returned punts based on the current distribution observed in the data (i.e., 47% return rate), and are further adjusted based on r

Estimating the Number of Concussions via Simulation

Non-Returned Punts: We use the base concussion rate for these plays to estimate the expected number of concussions (0.14%)

Returned Punts:

- We use bootstrap sampling for the distance to the sideline
- We use the logistic regression model from slide 8 to obtain $P(\text{Concussion Sustained}|\text{Distance from Sideline})$
- The average shift towards the sideline is simulated from a normal distribution with mean s_d and standard deviation 7 yards (equal to the standard deviation of the dataset), i.e., $\mathcal{N}(s_d, 7)$
- We show results for various values of the mean-shift, s_d

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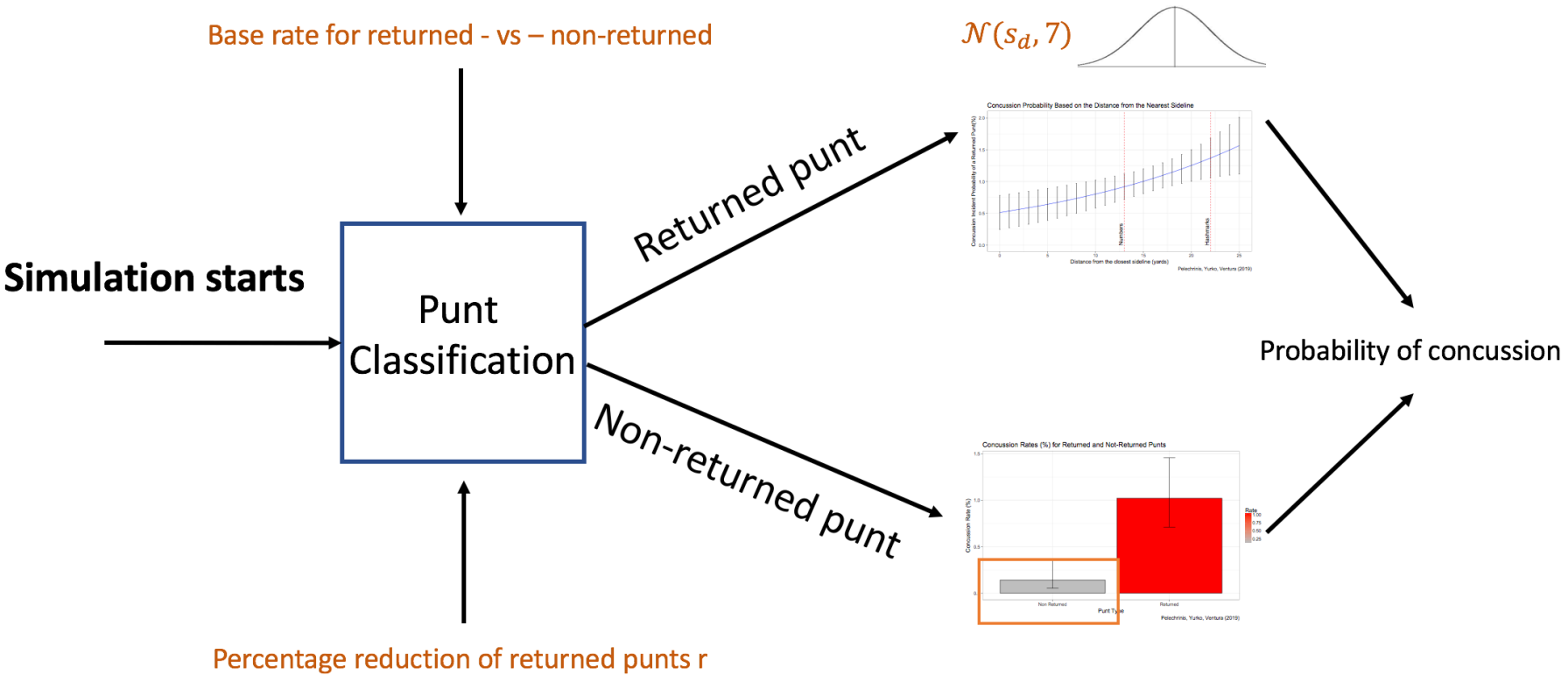
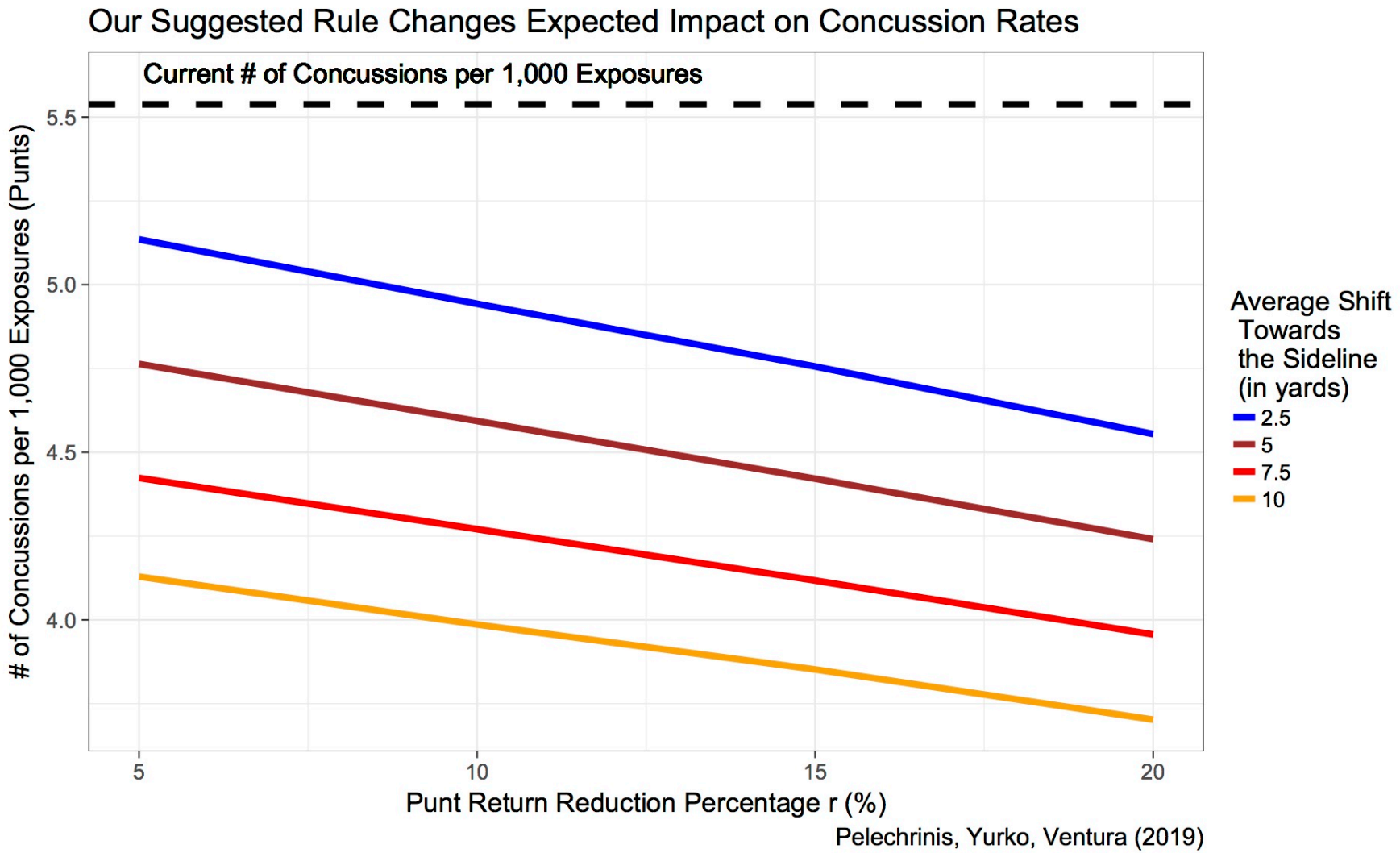


Results: How Many Concussions Will Be Prevented?



More punts towards sideline (higher shift s_d) $\rightarrow$ **fewer concussions**

Results: How Many Concussions Will Be Prevented?

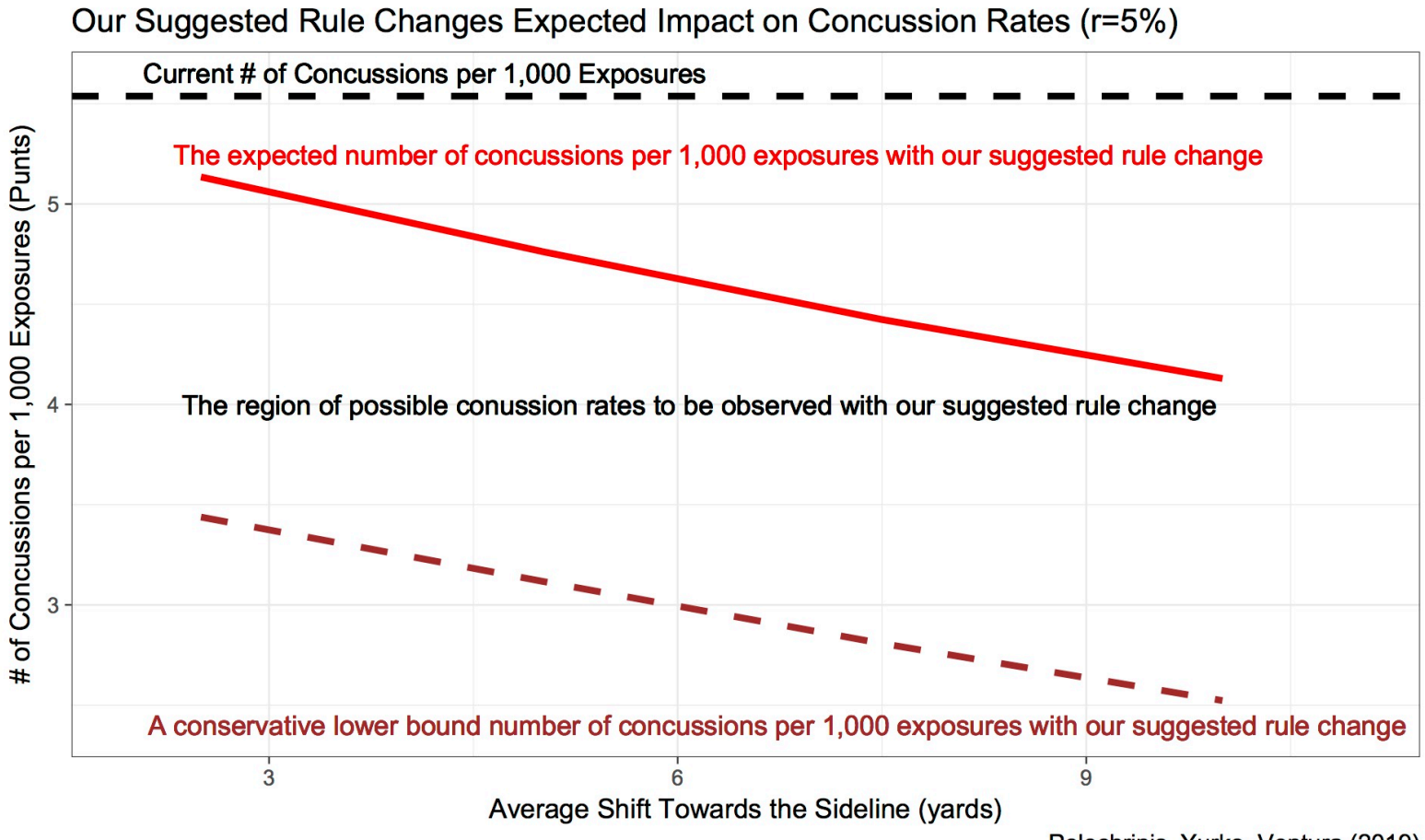
Our simulations consider a wide range of scenarios, from very conservative (blue line) to more optimistic (yellow line)

While we cannot know how teams will react to these rule changes, the outlook is promising:

- With a **conservative estimate** of a 5% reduction in returned punts and a slight shift of the punt of 2.5 yards towards the sideline, there would be a **7% reduction in the concussion rate**
- With a more **optimistic estimate** of a 20% reduction in returned punts and a large shift of the punt of 10 yards towards the sideline, there would be a **33% reduction in the concussion rate**

Results: How Many Concussions Will Be Prevented?

If we account for the inherent **uncertainty of the estimated rates**, a conservative lower-bound on the concussion rate (and $r = 5\%$) would lead to a **37% reduction of the concussion rate**



Pelechrinis, Yurko, Ventura (2019)

Discussion

Potential Unintended Consequences of Rule Changes

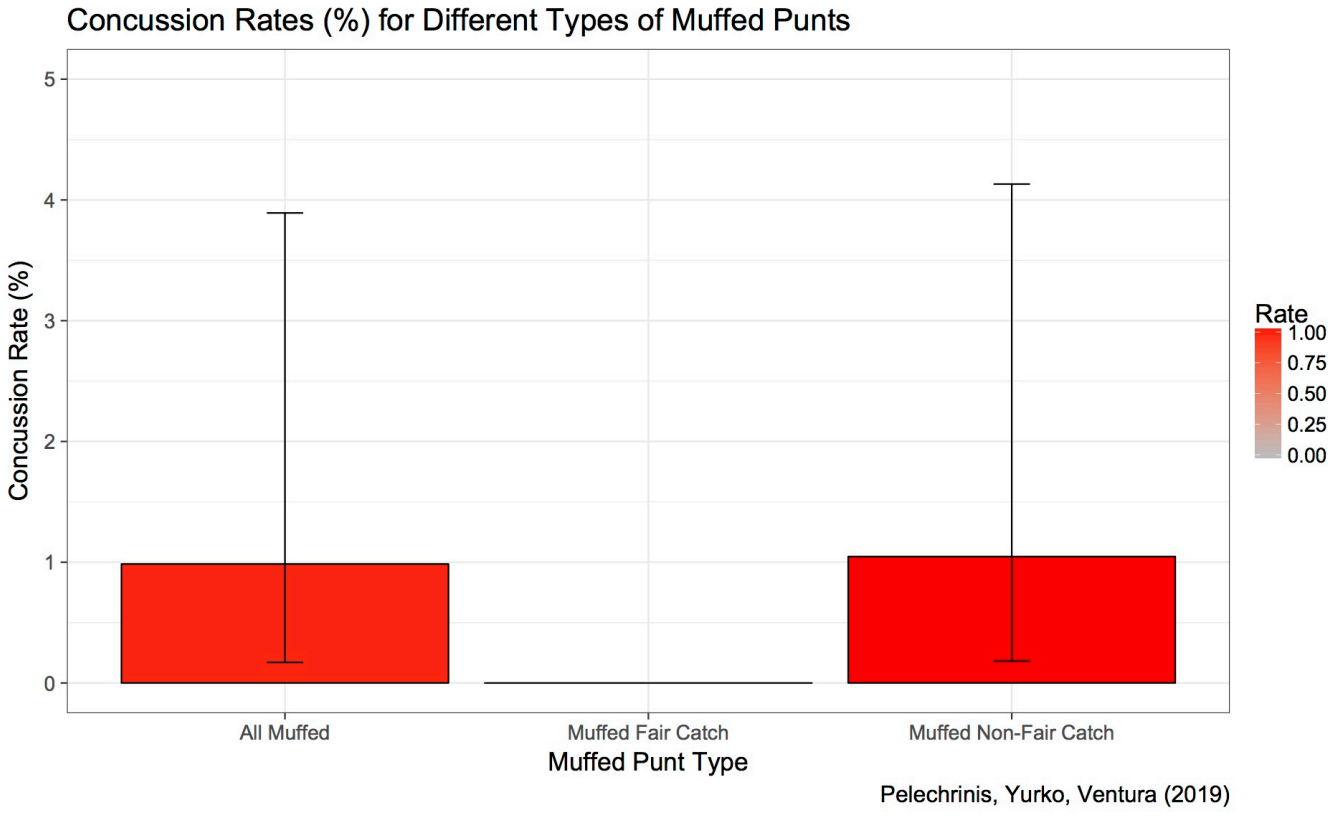
As with any change, unintended behaviors might be triggered.

In our case, potential unintended consequences could include:

- The punt returner attempts to make a difficult fair catch to gain the 5-yards incentive, when under the current rules he would let the punt to land and be downed
- The rate of muffed punts could increase

Do muffed punts have *high* concussion rates?

Concussion Rates for Muffed Punts

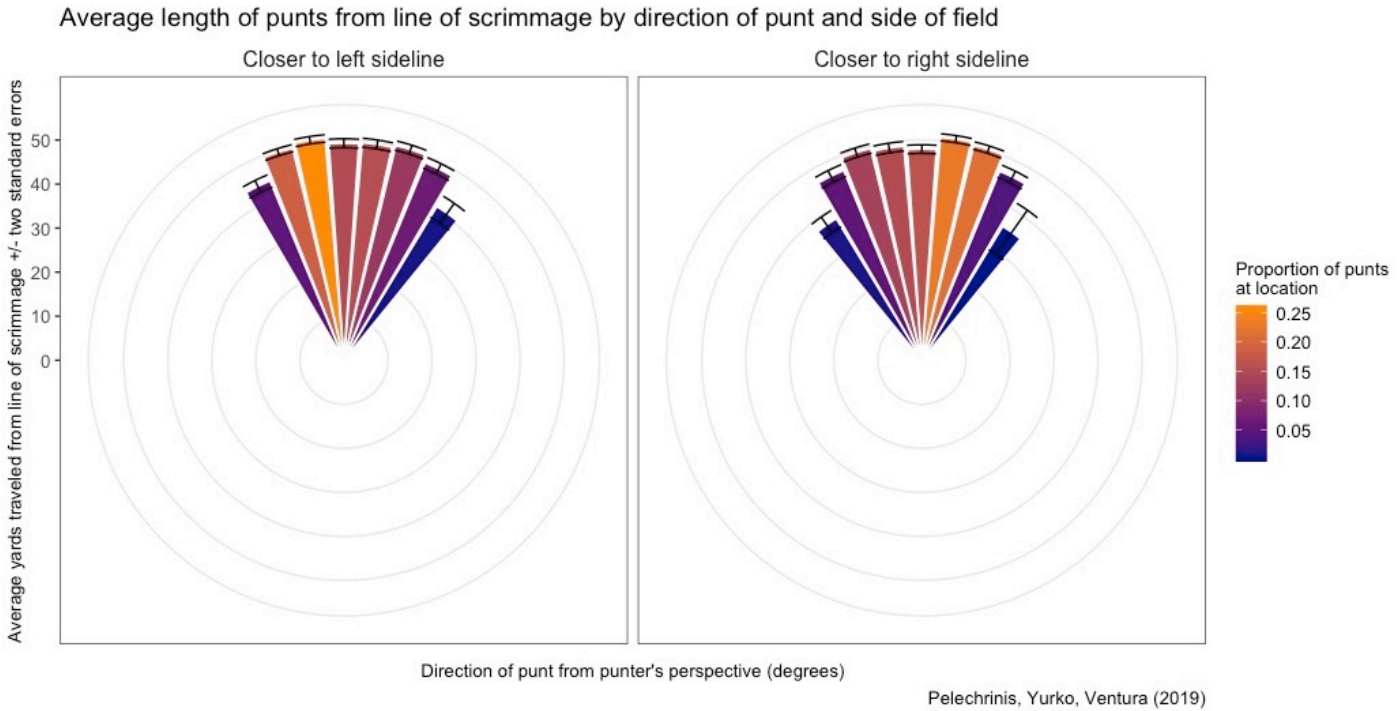


Overall, muffed punts have high concussion rates, but **only when the punt was *not* signaled for a fair catch!**

There were **no concussions** sustained on **muffed punts** that were **signaled for a fair catch** in the dataset.

Will There Be a Reduction in Punt Distance?

If teams punt towards the sideline rather than straight ahead, will that reduce the punt's net yards, nullifying the 5-yard OOB incentive?



Punts kicked on non-extreme angles have roughly equal net yards as those kicked straight ahead

Teams already angle their kicks toward the nearest sideline, so any change in behavior will not be drastic

Why Not Make Changes in the Touchback?

Touchbacks have low concussion rate as well

Incentivizing more touchbacks could potentially further reduce the overall concussion rates **but**:

- Punts that can become touchbacks are fewer
- Adding a rule change for the touchbacks can add confusion to fans, officials and the clubs

Why Not Do Away With Punts Altogether?

We are not in favor of drastic changes to the game

Our proposals are in line with prior changes to kickoff rules:
We provide incentives to make punt plays safer,
while avoiding eliminating punts altogether

If punts are eliminated, ball placement on a change of possession would be a contentious and challenging subject

Punts are exciting plays that fans enjoy
and that can impact games…

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Appendix

Logistic Regression Model for Concussion Likelihood

We use a logistic regression model to estimate the likelihood of a concussion incident on a returned punt as a function of the distance from the closest sideline that the ball was received

The response variable Y is binary and represents the occurrence of a concussion ($Y = 1$) or not ($Y = 0$)

The model estimates the probability of $Y = 1$, as a function of a set of covariates $\mathbf{x}$, i.e., $Pr[Y = 1|\mathbf{x}] = \frac{1}{1 + e^{-\mathbf{b}^T \cdot \mathbf{x}}}$

- Our model has a single covariate, namely, the distance to the closest sideline when the punt returner receives the punt

Generalized Additive Model for Win Probability

We use a **generalized additive model (GAM)** to estimate the possession team's probability of winning the game conditional on the current game situation

Semi-parametric approach captures nonlinear relationships while maintaining the many advantages of using linear models

Variables include **expected score differential** (using expected points model), interactions with the time remaining, game half, and timeouts remaining for both teams

Model Punts with Mixture of von Mises-Fisher Distributions

Finite mixture models provide model-based approach for clustering:

$$f(\mathbf{x}|\Theta) = \sum_{k=1}^{K} \pi_k f_k(\mathbf{x}|\theta_k)$$

- $\Theta = (\pi_1, \ldots, \pi_k, \theta_1, \ldots, \theta_k)$, where $\pi_k > 0$, such that $\sum_{k=1}^{K} \pi_k = 1$

Use **mixture of von Mises-Fisher distributions** to cluster punts

$$f_k(\mathbf{x}|\mu_k, \kappa_k) = c_d(\kappa_k) e^{\kappa_k \mu_k^\top \mathbf{x}}$$

- $\mathbf{x} = d$-dimensional unit vector ($\mathbf{x} \in \mathbb{R}^d$ and $\|\mathbf{x}\| = 1$, or $\mathbf{x} \in \mathbb{S}^{d-1}$)
- $\mu_k =$ **mean direction of punt cluster** k, $||\mu_k|| = 1$
- $\kappa_k =$ **concentration parameter**, $\kappa_k \geq 0$ (ie inverse of variance)

Clustering results revealed no underlying group structure of punts besides punting towards nearest sideline