The Power of Proximity - Using Network Science to Analyze the Link Between Coaching Communities and Team Success in the National Football League

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The National Football League has continued to place a premium emphasis on coaching. Anecdotal evidence reveals the ability of an elite coaching staff to lift the team around them, and a well-oiled coaching unit seems to have a clear impact on winning. Despite coaching being a seemingly important aspect of the game, little research has been done on the relationship between coaching staff chemistry and team success. With limited publicly available data, we constructed a comprehensive coaching network. We used this dataset to create modern coaching communities and identify the effect of coaching chemistry on team success.

NFL | Coaching tree | Social networks | QSS41

The relationship between coaches in the National Football League (NFL) is often discussed in terms of coaching trees. A coaching tree typically illustrates the influence of a head coach on other head coaches, showing how coaches branch out from one another through mentorship or direct relationships. While these trees are valuable in understanding the spread of coaching philosophies across the league, they primarily operate in a linear, one-directional manner. They also typically only include head coaches which does not account for the connections between coordinators and lower-level coaches. To broaden the coaching tree, we have created a comprehensive coaching network to try to critically examine the impact of coaching connections on team success.

Pre-existing research literature on this subject has established that NFL Coaches have a significant impact on team success. A study from the University of Chicago found that NFL coaches explain 18 to 25 percent of within-team, between season variation in points allowed and point margin (1). Similar research has looked at which types of coaching styles lead to most team success. One study conducted at Praire View A&M University found a significant impact between a transformational head coach leadership style and team success, indicating that coaching style and philosophy also impacts success (2). However, many of these studies use dated data that inaccurately reflect the relevant coaches present in the NFL today. They also restrict their network to head coaches lacking crucial connections between head coaches, coordinators, and lower-level coaches. Building on prior research, our comprehensive network reflects the full, multidimensional nature of NFL coaching relationships across all levels between 2010 and 2014.

Significance Statement

The relationship between coaches in the National Football League is one of the most overlooked aspects of the game. With little publicly available data, we have created a comprehensive dataset that maps the connections of over 6600 head coaches, coordinators, positional coaches, and quality control coaches from 2010 to 2024. Using this data, we have conducted several points of analysis. First, we established modern coaching trees that include lower-level coaches. Each tree is a distinct coaching community based on connection strength and coaching philosophy. Next, we used separation theory to map the distance between every coach in our dataset to Kyle Shanahan. Lastly, we created three regression models to test the effect of coaching staff chemistry on team success. Our findings suggest that close-knit coaching staffs have a positive, statistically significant effect on team success, providing valuable insights to NFL teams.

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Using our new dataset, we first formed clustered coaching communities to find close relationships and coaches with common philosophies. We also measured nodal distances from Kyle Shanahan to see the connectivity of the network and the centrality of Shanahan. Finally, we performed linear and logistic regressions to determine the significance of increasing the strength of coaching staff connection on team success.

Data

Data collection. We forged a dataset of 6,695 coaches using raw coaching data from pro-football-history.com (3). This site contains basic coaching information for all NFL teams, notably the personnel's names and roles. The coach's name, specific position, team, and year were all transcribed in our dataset. We included head coaches, coordinators, positional coaches, and quality control coaches in our analysis. Assistant coaches were disregarded due to their smaller role in the team's overall team success. Only assistant head coaches were retained and rated equivalent to coordinators. We included offensive, defensive, and general Quality Control Coaches, who are responsible for reviewing film and analyzing statistical data. We included them because of a well-established pipeline from quality control to head coach, with some notable current examples being Shanahan, Nick Sirianni, and Demeco Ryans. Including quality control coaches allowed us to track these pipelines from their starting points. In addition to general information about each coach, we included binary variables that indicated whether a given coach was fired, promoted, an assistant coach, an interim head coach, and an interim coordinator. Finally, if a coach had multiple roles in the same year, we only listed them once to avoid redundancy. **Figure 1** shows the distribution of coaches in our dataset.

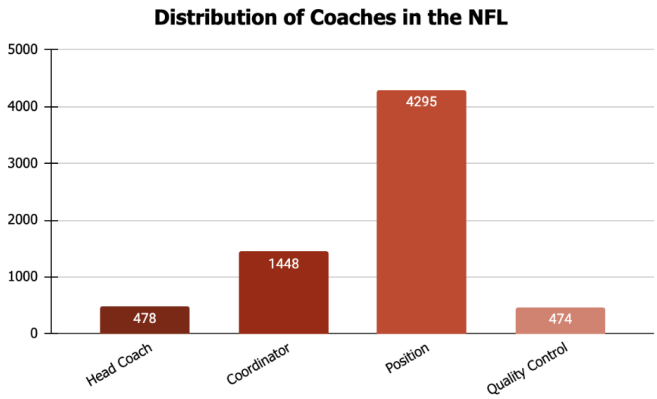


Fig. 1. Distribution of coaches - 2010-2024

As observed, the majority of coaches are positional coaches, followed by coordinators.

Defining tie strength. Football teams have an extensive coaching hierarchy. Different coaching roles have varying levels of authority; head coaches have formal authority, coordinators (Offense, Defense, Special Teams) have decision-making authority, and positional coaches have sanctioning authority. Correspondingly, coaches also have varying levels of impact on team success, with head coaches being the most influential. We assigned numerical values to each coaching role to mirror their level of authority and impact. Head coaches received a rating of 10, coordinators received a rating of 7.5, and positional coaches received a rating of 5. If a coach had roles at two levels (i.e. a coordinator and positional coach), we chose the higher-value position to assign a value (7.5). This is consistent with previous literature, as shown in **Figure 2** (4).

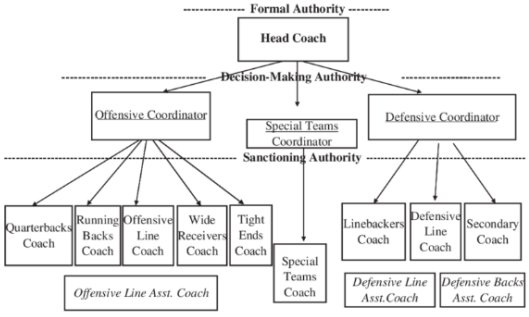


Fig. 2. Coaching hierarchy

Just as not every coach has the same authority, every connection between two coaches should not be weighted the same. A head coach and offensive coordinator working together for several years should theoretically impact team success more than two positional coaches working together for the same amount of time. The head coach and coordinators are connected in the hierarchy, indicating they spend more time together to determine how game plans will be implemented, and they have the highest authority. Following this logic, we determined a connection between two coaches to be the **sum of their ratings** in a given year. For instance, a head coach and offensive coordinator's connection would be 17.5 for a single year. Coaches' situations can change greatly from year to year — they can leave their team, join another team, get promoted, or get demoted. Thus, it is possible that a coaching pair's rating changes from year to year. Now that each coaching pair has a *connection rating* for a given year, we created an **Aggregated Closeness Score**, the cumulative sum of a coaching pair's connection ratings up to that year. For example, if two coaches coached together as head coach and offensive coordinator in 2013, 2014, and 2015, their aggregated closeness score would be **52.5** in 2015. The aggregated closeness score accounts for both the connection strength and authority of the two coaches, as well as the time spent together. The aggregated closeness score was our final connection weight. Our 6695 nodes created **44435** connections. Since each year produced an aggregated connection score, for the visualizations, we only kept the most recent score between two coaches.

Pruning. In the current network, the vast majority of connections had a low weight, indicating a weak strength of connection between coaches. To make the visualizations less cluttered and more interpretable, as well as to set a higher threshold for the strength of a connection, we applied a threshold pruning technique. Any edge with a weight less than 50 was removed and if a node did not have any connections greater than 50, it was also removed. While the value of 50 seems arbitrary, it represents an established coaching relationship. Connections that would eclipse the aggregate closeness score threshold of 50 are a head coach-coordinator connection for three years, a coordinator-positional coach connection for four years, and a positional-positional coach connection for five years. With the average NFL head coach tenure being approximately three years (5), we believed that the aggregate closeness score of 50 was a good benchmark for a strong connection to be established.

Clustering methods

With the network pruned, we decided to split it into distinct *coaching communities*. To do this, we applied a fast-greedy modularity maximizing algorithm to the data. Modularity maximizing techniques prioritize maximizing the number of in-group connections and minimizing the number of our-group connections. As a result, distinct coaching communities will form and are appropriately labeled and grouped. Coaches will likely have many ties within their communities, and thus, coaching style or philosophy might potentially be spread across a community. The algorithm produced 19 distinct communities. While we wanted the communities to be created quantitatively, we still wanted each community to resemble a coaching tree. Thus, we had to evaluate if the 19 resulting communities were significant. We decided to qualitatively evaluate each community and determined significance based on two questions:

1. How many head coaches, former head coaches, and established coordinators are in the community?
2. Are the network's head coaches and former head coaches known to follow a similar style of coaching?

Based on the above criteria, **13** of the 19 communities were determined to be significant. We decided to name each community after a well-known coach who is known to have influence within the network.

Figure 3 displays the *Shanahan community*, named after San Francisco 49ers head coach Kyle Shanahan.

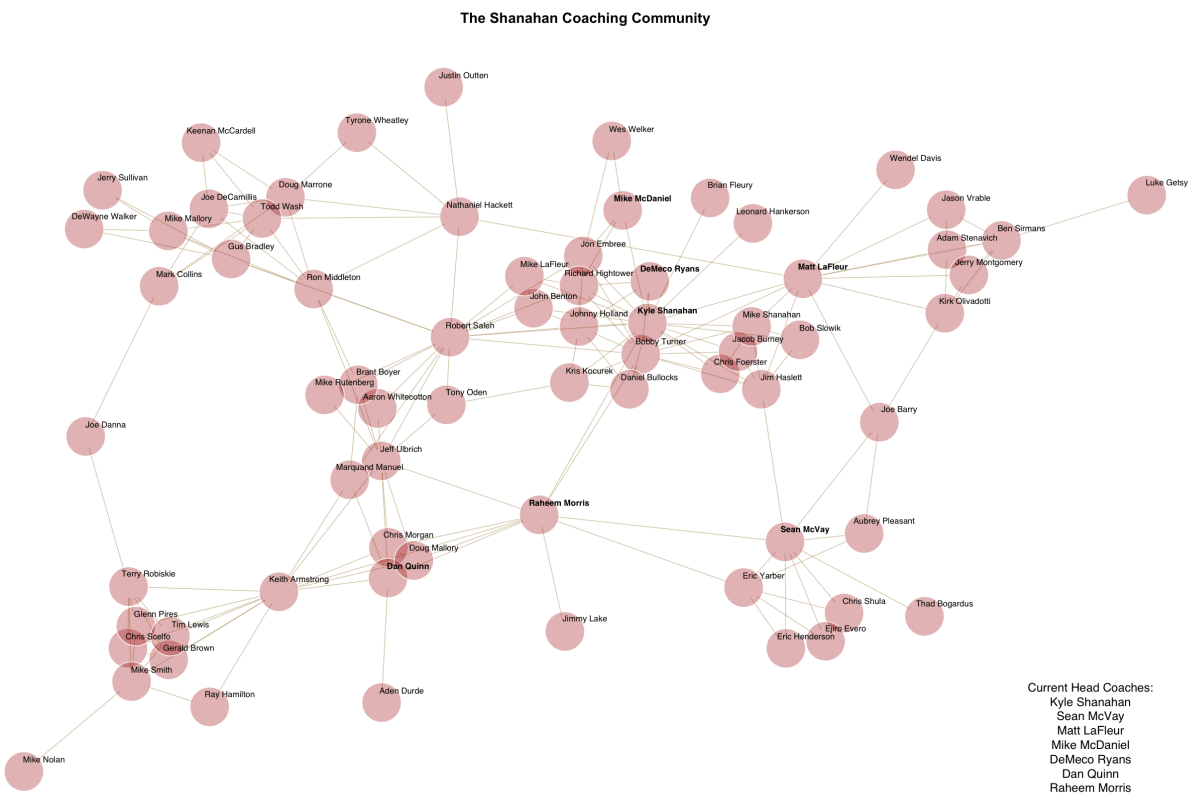


Fig. 3. Shanahan coaching community

The Shanahan community is the largest coaching community, boasting over 70 coaches and seven active head coaches. The success of Shanahan and the 49ers has motivated other teams to hire his coordinators as head coaches, emphasizing his influence over the rest of the league. Analyzing the Shanahan network deeper, there is obvious evidence of bridges, where nodes are connecting two otherwise separate communities. For example, Joe Danna, the current Safeties Coach for the Buffalo Bills connects Joe DeCamillis' neighborhood with that of Tim Lewis. Raheem Morris also acts a connector between Dan Quinn's section of the network and the more central part with Kyle Shanahan and DeMeco Ryans. Moreover, there is a recurring structural motif of lower-level less well-connected coaches funneling into a head coach who then connects to the central node. Raheem Morris, Sean McVay, and Matt LaFluer are all prime examples of this behavior.

Figure 4 displays the *Payton community*, named after current Denver Broncos head coach Sean Payton. Analyzing the Shanahan network, there is obvious evidence of bridges, where nodes are connecting two otherwise separate communities. For example, Joe Danna, the current Safeties Coach for the Buffalo Bills connects Joe DeCamillis' neighborhood with that of Tim Lewis.

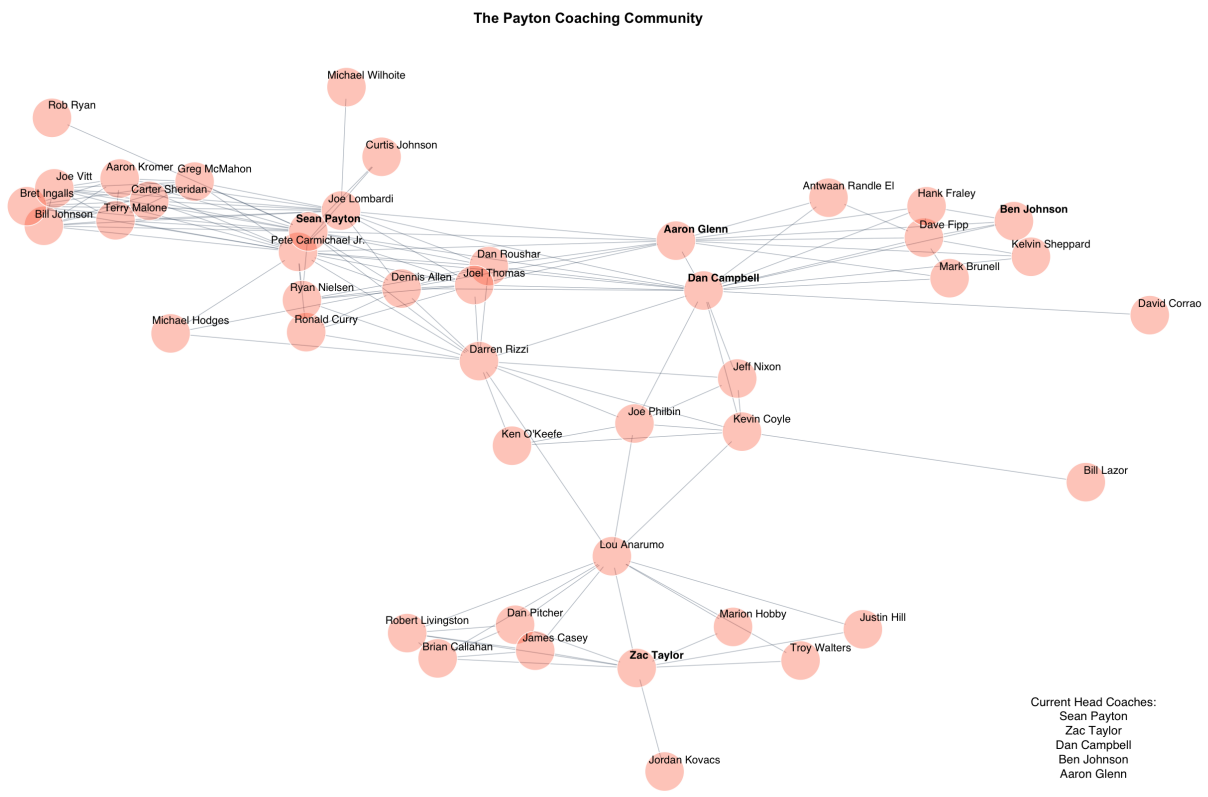


Fig. 4. Payton coaching community

Although smaller in size compared to the Shanahan community, the Payton community has picked up recent steam after Lions head coach and Payton disciple Dan Campbell's coordinators Ben Johnson and Aaron Glenn recently received head coaching opportunities. While never a head coach, long-time defensive coordinator Lou Anarumo serves as a bridge between Sean Payton and an evergrowing Zac Taylor/Brian Callahan sub-community. Additionally, several of Sean Payton's close connections seemed to have formed a clique, showing that they have been coaching together for a very long time. The stability of the 2010's New Orleans Saints coaching staff may have contributed to their sustained success. Six current head coaches make the Payton community the second most significant within the NFL network.

Figure 5 showcases the *Reid coaching community* named after Kansas City Chiefs head coach Andy Reid.

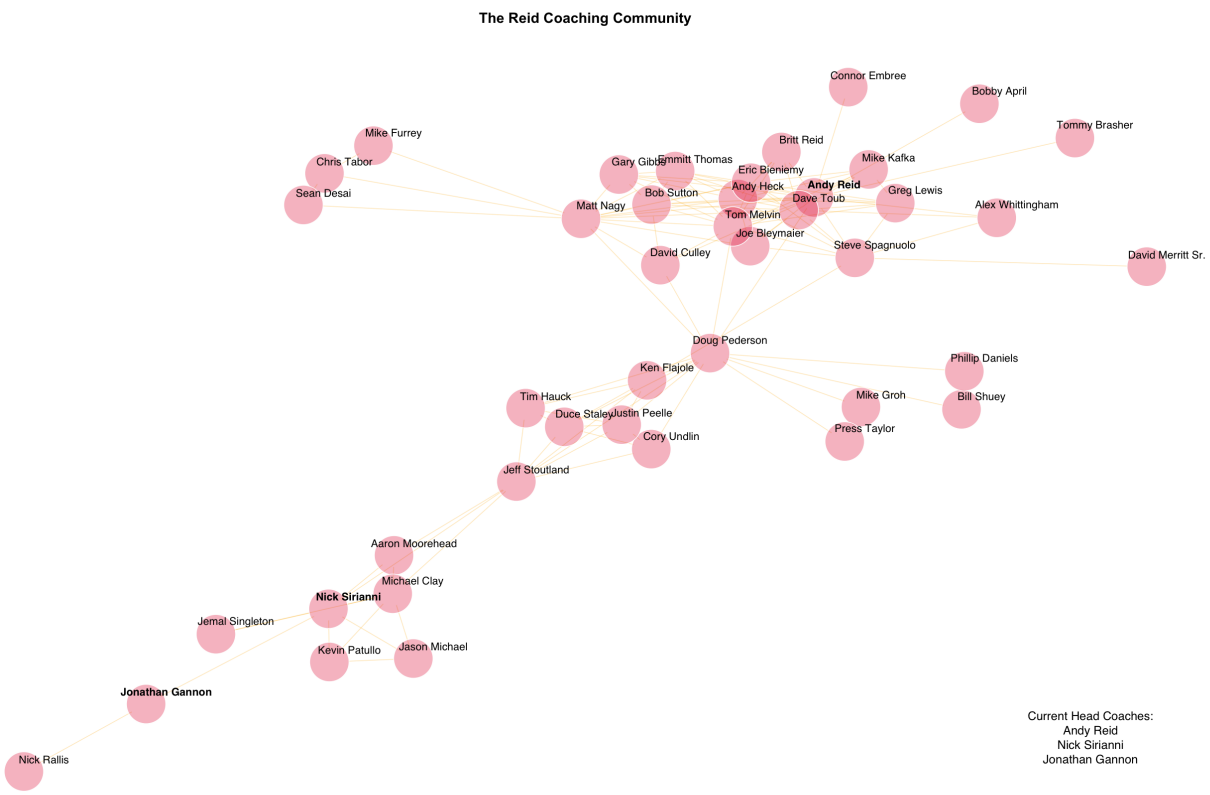


Fig. 5. Reid coaching community

The community is home to three active head coaches. While not directly connected to Reid, Eagles head coach Nick Sirianni and his former defensive coordinator, Arizona Cardinals head coach Jonathan Gannon find themselves in this community.

Other notable communities include:

- **Belichick community** named after former Patriots great Bill Belichick. While there are over 50 coaches in this community, current Patriots head coach Mike Vrabel is the only active head coach.
- **Rivera community** named after former Panthers and Commanders head coach Ron Rivera. Bills head coach Sean McDermott and his former offensive coordinator, Giants head coach Brian Daboll, make up the active head coaches in this community.
- **Carroll community** named after Raiders head coach Pete Carroll. Despite only having 24 coaches, the community has multiple active head coaches: Panthers head coach Dave Canales and Cowboys head coach Brian Schottenheimer.
- ***John* Harbaugh community** named after Ravens head coach John Harbaugh. Seahawks head coach Mike MacDonald belongs to this community.
- **Fangio community** named after Eagles defensive coordinator Vic Fangio. This is a community popular amongst defensive coordinators as opposed to head coaches. The sole active head coach is Jim Harbaugh of the Chargers.
- The **Lewis/Zimmer community** named after Marvin Lewis and Mike Zimmer contains Vikings head coach Kevin O'Connell and Browns head coach Kevin Stefanski.
- The **McCarthy community** named after Mike McCarthy contains Saints head coach Kellen Moore.
- The **Tomlin community** named after Steelers head coach Mike Tomlin does not contain any other active head coaches. However, it could be merged with the **Arians community** named after Bruce Arians that contains Buccaneers head coach Todd Bowles. Arians was a coordinator for Tomlin before our data was recorded.
- The **Garrett/Gruden community** named after Jason Garrett and Jon Gruden is our first *extinct* group. Matt Eberflus was the last head coach.

Our coaching clustering algorithm has put 30 of the 32 active NFL head coaches into distinct communities. Colts head coach Shane Steichen was put into a community we determined to be insignificant. However, we would place him in the *Reid community* due to his connection to **Nick Sirianni**. New Jaguars head coach Liam Coen was removed from the network during the pruning process since he had only one season in a major coaching position. Since Coen was an assistant with the Rams for a few years and tributes his offensive philosophy to Sean McVay, we would place him in the *Shanahan community*.

The Shanahan Score

As mentioned earlier, Kyle Shanahan's community is the largest with the most active head coaches. It is also believed that many teams are trying to imitate Shanahan's play-style to reproduce some of the success he's achieved. So just how embedded is Kyle Shanahan? To answer this question, we created *The Six Degrees of Kyle Shanahan* - a twist on the Six Degrees of Separation. The theory of separation follows the idea that one node can reach another node in no more than six steps (14), (6). Instead of counting the number of connections, we decided to use a distance formula, where

$$C = \frac{1}{\alpha} + \frac{1}{\gamma}$$

is the closeness score, α is the *aggregated closeness score*, and γ is the number of years coached together. With this formula, coaches with higher aggregated closeness scores will have a lower distance, making them closer to Shanahan.

With the distances calculated, we calculated the shortest path between Shanahan and every coach from our pruned network. Some notable results are displayed in **Figure 6**.

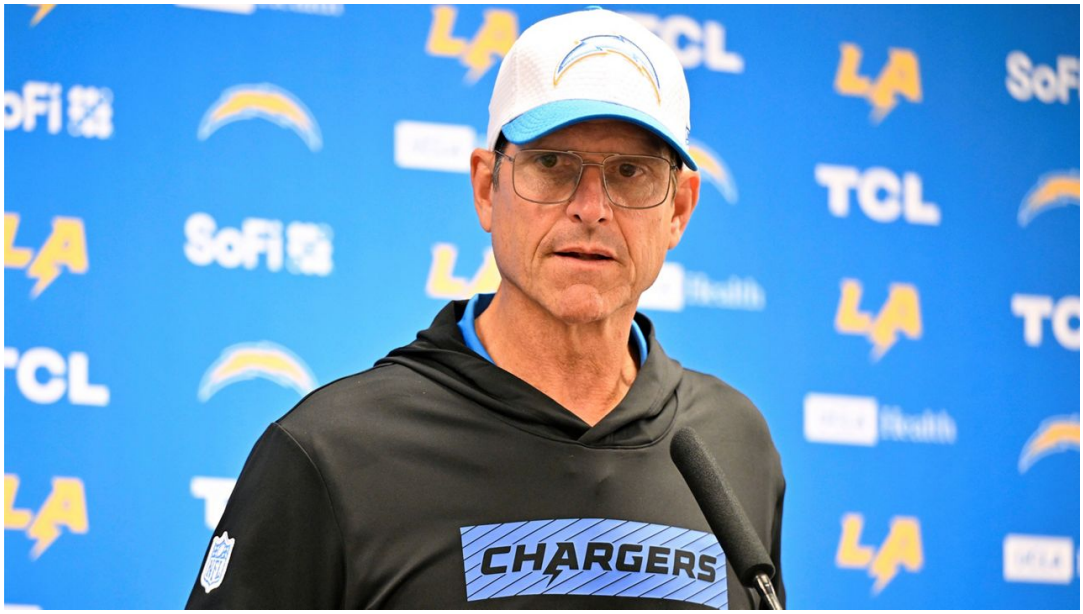
How close are major head coaches to Kyle Shanahan?

	Coach Name	Path	Score
1	Matt LaFleur	Kyle Shanahan - Matt LaFleur	0.18
2	DeMeco Ryans	Kyle Shanahan - DeMeco Ryans	0.213
3	Mike McDaniel	Kyle Shanahan - Mike McDaniel	0.213
4	Raheem Morris	Kyle Shanahan - Raheem Morris	0.27
5	Sean McVay	Kyle Shanahan - Bobby Turner - Sean McVay	0.35
6	Mike Tomlin	Kyle Shanahan - Danny Smith - Mike Tomlin	0.444
7	Pete Carroll	Kyle Shanahan - Brian Schneider - Pete Carroll	0.448
8	Shane Steichen	Kyle Shanahan - Robert Saleh - Gus Bradley - Shane Steichen	0.658
9	Kevin O'Connell	Kyle Shanahan - Bobby Turner - Sean McVay - Wes Phillips - Kevin O'Connell	0.682
10	Sean McDermott	Kyle Shanahan - Matt LaFleur - Ben Sirmans - Rob Boras - Sean McDermott	0.765
11	Dan Campbell	Kyle Shanahan - John Benton - Darren Rizzi - Dan Campbell	0.781
12	Mike Vrabel	Kyle Shanahan - Jim Haslett - Mike Vrabel	0.8
13	Andy Reid	Kyle Shanahan - Jon Embree - Joe Cullen - Andy Heck - Andy Reid	0.817
14	Mike Macdonald	Kyle Shanahan - Jon Embree - Joe Cullen - Mike Macdonald	0.82

Fig. 6. Distance rankings from Shanahan - Major head coaches

The first five head coaches all coached alongside Shanahan at some point in their career, representing a direct connection. While Sean McVay coached with Kyle Shanahan, going through the intermediary Bobby Turner yielded a closer score. The

most extensive path (including non-head coaches) was six degrees. This exercise is an illustration for how embedded the NFL coaching community truly is. Since there are hundreds of coaches, many of which switch teams every year, philosophies are mixed and exchanged, making the NFL so dynamic and everchanging. The 2023 Los Angeles Chargers finished the season with five wins and 12 losses, good for the sixth worst record in the NFL. Instead of replenishing their roster in the off-season, the Chargers parted ways with two key contributors: wide receivers Keenan Allen and Mike Williams. However they made one key move: hiring University of Michigan head coach Jim Harbaugh. They gave Harbaugh autonomy, allowing him to have input in hiring his coaching staff. Harbaugh ended up bringing on several of Harbaugh's close connections. Heading into 2024, the Chargers had a dynamic, well-connected coaching staff, but arguably a worse roster than 2023. Despite this apparent deficiency, the Chargers ended up winning 11 games, more than doubling their previous season's win total.



While they ended up losing in the first round of the playoffs, the 2024 Chargers are a prime example for how a well-connected coaching staff can greatly elevate the team around them. Is the *Harbaugh effect* a global phenomenon? In other words, does the closeness of a team's coaching staff impact the team's success?

To answer this question, we first defined a *Team Closeness Score*, representing how well a team's coaching staff was connected. We set the team closeness score equal to

$$\frac{1}{N}\sum_{i=1}^{N}(\alpha+\gamma)$$

where α represents the aggregated closeness score and γ represents the years coached together. In other words, the team closeness score is the average of the connection strength between every combination of two coaches on a coaching staff. The result was a dataset that contained the closeness score of every team from every year.

We then joined our team score data with team standing data from nflfastR, which provided team records, win percentage, playoff seeding, and strength of schedule (8). With our data properly wrangled, it was now possible to see if coaching staff closeness has a significant impact on team success.

We created three models. All three models included Team Closeness Score as a predictor and included strength of schedule and the previous year's win percentage as control variables. The latter control was included to prevent autocorrelation. The first model we created was a *linear regression model* that tested the relationship between coaching staff closeness and *win percentage*. We decided to choose win percentage as opposed to total wins since teams played one fewer game prior to 2021 (**?**). The next two models were *logistic regression models*, attempting to predict whether or not the team made the playoffs and whether or not they won the division respectively. Based on anecdotal evidence, we hypothesized that coaching chemistry would have a positive, significant impact on all metrics of team success.

The results of the first model are visualized in **Table 1**.

As we can see, Team Closeness Score has a positive, statistically significant effect on win percentage. While the coefficient of 0.0038 does not seem significant, Team Closeness Score ranges from 10 to 95. As coaches become familiar with each other and coach together for longer, the team closeness score increases significantly. According to the model, if a team's closeness score increases by 16, their win percentage will increase by 0.06 which is roughly equivalent to one game in a 17-game season.

Table 2 visualizes the effect of Team Closeness Score on playoff probability.

Table 1. Effect of coaching staff closeness on team win percentage

	Estimate	Std. Error	t Value	Pr($>\|t\|$)
Coefficients				
Intercept	1.6557	0.103874	15.940	$< 2.0 \times 10^{-16***}$
Closeness Score	0.0038	0.0004558	8.402	$5.15 \times 10^{-13***}$
Lag Win %	0.2309	0.0369745	6.245	$< 9.43 \times 10^{-10***}$
Strength of Schedule	−2.8151	0.2014151	−13.977	$< 2.0 \times 10^{-16***}$

Notes: ***/**/* denotes significance at the 5/1/.1 percent.
Residual standard error: 0.1392 on 474 degrees of freedom
Multiple R-squared: 0.473, Adjusted R-squared: 0.4697
F-statistic: 141.8 on 3 and 474 DF, p-value: < 2e-16

Table 2. Effect of coaching staff closeness on team playoff probability

	Estimate	Std. Error	z Value	Pr($>\|z\|$)
Coefficients				
Intercept	13.3461	2.0616	6.474	$< 2.0 \times 10^{-16***}$
Closeness Score	0.0525	0.0092	5.726	$1.03 \times 10^{-7***}$
Lag Win %	2.3590	0.6689	3.527	$4.21 \times 10^{-4***}$
Strength of Schedule	−33.9313	4.3035	−7.885	$< 2.0 \times 10^{-16***}$

Notes: ***/**/* denotes significance at the 5/1/.1 percent.
Null deviance: 642.41 on 477 degrees of freedom
Residual deviance: 472.73 on 474 degrees of freedom
AIC: 480.73

The closeness score once again has a positive, statistically significant association with team playoff probability. Converting log-odds to probabilities, a one increase in team closeness is associated with a **1.5 percent increase** in playoff probability. **Table 3** visualizes the effect of coaching closeness on *division winning probability*.

Table 3. Effect of coaching staff closeness on division winning probability

	Estimate	Std. Error	z Value	Pr($>\|z\|$)
Coefficients				
Intercept	12.9996	2.2953	5.664	$1.48 \times 10^{-8***}$
Closeness Score	0.0418	0.0088	4.763	$1.91 \times 10^{-6***}$
Lag Win %	3.4843	0.7792	4.472	$7.76 \times 10^{-7***}$
Strength of Schedule	−35.6366	4.8895	−7.288	$3.14 \times 10^{-11***}$

Notes: ***/**/* denotes significance at the 5/1/.1 percent.
Null deviance: 538.69 on 477 degrees of freedom
Residual deviance: 389.81 on 474 degrees of freedom
AIC: 397.81

Similar to above, closeness score has a statistically significant, positive effect on divisional winning probability. Converting log-odds to probability, a one increase in team closeness is associated with a **1.4 percent increase** in the probability a team wins the division.

After testing Team Closeness Score on three different metrics to measure team success, we can conclude that the connectivity of a coaching staff has quite an effect on team performance.

Direct takeaways

Our findings show that strong relationships among coaches play a crucial role in team success. Rather than cleaning house after a disappointing season, organizations should value keeping staff together to build deeper connections over time. Moreover, when hiring, teams should look closely at candidates who already have solid working relationships with current coaches. Someone who has a positive history with the head coach will likely strengthen the overall coaching network and improve team dynamics. Our model involves rating connections between top-level leadership at a higher weight than those among position or quality control coaches, which makes sense given that head coaches and coordinators make the most important decisions. Thus, increasing chemistry between head coaches and coordinators is crucial. These upper-level coaches should thus have significant influence on decision-making with respect to coaching staff.

Limitations

While our network analysis is extensive and yielded worthwhile results, there are a number of improvements to be made. First and foremost, our dataset is fairly recent, only containing records as far back as 2010. Pre-2010 data could impact connection scores, produce new clusters, and yield different results. Yet this data is necessary to include in order to effectively consider all extensive previous work history. In order to effectively account for all relationships, we should include information as early as 1973 when Pete Caroll – the oldest current head coach – began his career. Furthermore, by valuing all positional coaches and coordinators the same (5 and 7.5, respectively), we are assuming the strength of their relationships are equivalently impactful to team success. In actuality however, it is possible (and likely) that the quarterback coach's relationship to the offensive coordinator matters more than that of the defensive line's coach to the offensive coordinator. Building off that point, a quarterback coach could have a greater impact on success than the cornerback's coach, yet our analysis weighs both positions equally. Finally, as with all studies, there is potential omitted variable bias. Though we controlled for strength-of-schedule and previous year performance, we must acknowledge that numerous factors beyond coaching relationships influence team outcomes—from roster construction and injury patterns to salary cap utilization and organizational stability. The multifaceted nature of NFL success means our findings demonstrate significant correlations rather than direct causation. Our statistical models, while revealing meaningful patterns, explain only a portion of performance variance, as reflected in the R-squared values. This suggests that team success ultimately stems from a complex interaction of multiple variables, many of which are outside the scope of our current analysis.

Future analysis

Looking ahead, we have several exciting paths to explore. We want to uncover hiring patterns both for individual teams and across the entire NFL. One such avenue would be to investigate whether franchises are quicker or less inclined to fire a specific position. We're also curious about whether teams deliberately recruit coaches from division rivals. This would be plausible as it simultaneously strengthens themselves while weakening frequently opposing teams. And if not, should this be a more common practice? Another question to explore would be if one team consistently cultivates strong coaches that are taken by other teams. We could investigate this by comparing the impact of success on past hirings. In addition, while we initially planned to analyze the impact of mid-season staff changes, time constraints limited us. This would be an interesting question to explore. We have data on whether coaches were fired mid-season, but we need to refine our dataset to properly measure how these changes affect resulting team performance. Finally, since many NFL coaches start their careers in college football, we plan to incorporate college coaching records from recent decades. This will give us a more complete picture of professional relationships, capturing connections that were formed and strengthened at the collegiate level.

Conclusion

Our comprehensive analysis of coaching relationships in the NFL reveals that team success is significantly influenced by the strength of connections within coaching staffs, with each one-point increase in team closeness score improving playoff probability by 1.05 percent and division winning probability by 1.04 percent. By mapping over 44,000 connections between 6,695 coaches across all hierarchical levels and identifying distinct coaching communities, we've created a revolutionary framework that moves beyond traditional coaching trees to quantify the impact of staff cohesion. This research provides valuable guidance and actionable insights to NFL franchises for maximizing coaching effectiveness through thoughtful hiring and retention strategies.

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