

# Scoring dynamics across professional team sports: tempo, balance and predictability

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## Abstract

Despite growing interest in quantifying and modeling the scoring dynamics within professional sports games, relative little is known about what patterns or principles, if any, cut across different sports. Using a comprehensive data set of scoring events in nearly a dozen consecutive seasons of college and professional (American) football, professional hockey, and professional basketball, we identify several common patterns in scoring dynamics. Across these sports, scoring tempo—when scoring events occur—closely follows a common Poisson process, with a sport-specific rate. Similarly, scoring balance—how often a team wins an event—follows a common Bernoulli process, with a parameter that effectively varies with the size of the lead. Combining these processes within a generative model of gameplay, we find they both reproduce the observed dynamics in all four sports and accurately predict game outcomes. These results demonstrate common dynamical patterns underlying within-game scoring dynamics across professional team sports, and suggest specific mechanisms for driving them. We close with a brief discussion of the implications of our results for several popular hypotheses about sports dynamics.

## A Game mechanics

Here we provide brief summaries of the game mechanics for each of the sports represented in our data set.

### **Professional and college football**

Both professional and college football games last 60 minutes, divided into four equal length “quarters.” Each of the two teams field 11 players, the identities of which are usually changed depending on whether a team has possession of the ball (offense) or not (defense). The field is a flat grass or turf surface 360 feet long and 160 feet wide. On either end of the field are two “end zones,” measuring 30 feet in length, one for each team.

The offense is given a series of four attempts (“downs”) to move the football 10 yards downfield from the last valid ball position, each of which must occur within 40 seconds of the last attempt’s end. Failure to move the ball the required distance results in the other team gaining possession. Points are scored by the team in possession when it moves the ball into the defensive team’s “end zone,” (a touchdown, 6 points) or passes the ball through the defensive team’s field goal (a field goal, 3 points). Scoring a touchdown provides the scoring team the opportunity for additional points, either through what would normally be a touchdown (2 points) or a field goal (1 point). Each team has three timeouts to use during gameplay, which are often used strategically near the end of the game. When time runs out, the team with the most points is declared the winner. For a complete description of professional and college level rules, see National Football Association (2013) and National Collegiate Athletic Association (2013) respectively.

### **Professional hockey**

A professional hockey game lasts 60 minutes, divided into three equal length “periods.” A game is played between two teams, each composed of six players (five skaters and one goalkeeper), whose identities change periodically throughout the game. Teams compete on an ice rink, 200 feet long and 85 feet wide. On either end of the rink are two nets, 6 feet wide and 4 feet high, one for each team.

Players on the team controlling the puck work together to move it into the opposing team’s net through a combination of strategic passes and shots. If the team is successful, a goal is scored and the team is awarded 1 point. The game plays continuously except after stoppages, which occur at minutes 6, 10, and 14, penalties, or goals. Each team has a single 30 second timeout that can be used at any point in the game. Teams use their timeouts to substitute players, adjust strategy and to provide the team with brief moments of rest during crucial periods of play. When time runs out, the team with the most

points is deemed the winner. For a complete description of rules, see National Hockey League (2013).

### **Professional basketball**

A professional basketball game lasts 48 minutes, divided into four equal length “quarters.” Each of the two teams field five players, whose identities change throughout the game. The court is a flat wooden surface, 94 feet long and 50 feet wide. On either side of the court are two circular rims, known as baskets, measuring 18 inches in diameter, positioned 10 feet above the court surface, one for each team.

A team in possession of the basketball has a total of 24 seconds to make a shot that it either hits the opposing team’s rim or goes through it. If time expires before the team attempts a shot, the opposing team gains possession of the basketball. Depending on game state and a player’s court location, a successful shot (one that goes through the opposing team’s rim) can be worth 1, 2, or 3 points. After scoring, the scoring team relinquishes possession of the basketball to the opposing team. Game play continues according to this procedure, except when the ball goes out of bounds or a foul is committed. Each team is awarded a single 20 second timeout per game half. Each team is also entitled to 6 more timeouts that may be used at anytime throughout the game, with the following restrictions: no more than 3 timeouts may be used during the final quarter and no more than 2 timeouts may be used within the final 2 minutes of play. These timeouts are used strategically to substitute players, control the speed of play, and facilitate the coordination and planning of complex plays. When time expires, the team that has accumulated the most points is deemed the winner. For a full description of game rules, see National Basketball Association (2013).

## **B Points per scoring event**

Table S1 shows the distribution of points per scoring event, for each sport. Events in the NHL only generate a single point. Although events in the NBA generate 1, 2 or 3 points, the large majority of events (74%) are worth 2 points, with the remaining events divided between 1- and 3-point shots.

Similarly, scoring events in both CFB and NFL games generally produce 7 points (touchdown with extra point). Games in CFB games from those in NFL in producing many more field goals (3 points) and many fewer touchdowns with no extra point (6 points), which are the next most common events in both. The remaining point values are relatively uncommon: 8 points for touchdowns plus a 2 point conversion play, and 2 points for a safety, which occurs in three scenarios: (i) when a ball carrier is tackled in his team’s own end zone; (ii)

when the ball is deemed dead by referees in the end zone, or (iii) when the offensive team commits a foul play in its own end zone. Two point conversions occur when the scoring team elects to successfully pass or run the ball into the end zone instead of kicking the ball through the field goal after a touchdown.

Figure S1 shows the fraction of total points in each game that are won by a team, which agrees very closely with the fraction of total scoring events, from Figure 4 (main text). This agreement indicates that only very rarely does the value of the points associated with events ultimately determine the outcome of a game. Instead, the chief determinant is simply number of events. In NHL games, this must be true as every event is worth the same number of points. A slightly deviation around 1/2 for NFL games, but not CFB games, indicates that very occasionally point values do matter.

point value	NFL	CFB	NHL	NBA
1	-	-	<b>1.0000</b>	0.0941
2	0.0083	0.0113	-	<b>0.7373</b>
3	0.3055	0.1702	-	0.1647
4	-	-	-	0.0029
5	-	-	-	0.0009
6	0.0308	0.0708	-	0.0001
7	<b>0.6222</b>	<b>0.7058</b>	-	-
8	0.0332	0.0419	-	-
any	1.0000	1.0000	1.0000	1.0000

Table S1: Empirical distribution of all regulation scoring events over point values, by sport, with the modal value highlighted.

## References

- National Basketball Association (2013): “Official rules of the National Basketball Association,” URL <http://on.nba.com/16Vmh1Z>, accessed 1 July 2013.
- National Collegiate Athletic Association (2013): “Football, rules and interpretations,” URL <http://bit.ly/1g18vTz>, accessed 1 July 2013.
- National Football Association (2013): “Official rules of the National Football Association,” URL <http://on.nfl.com/1bpjbMd>, accessed 1 July 2013.
- National Hockey League (2013): “Official rules of the National Hockey League,” URL <http://bit.ly/1hiPp92>, accessed 1 July 2013.

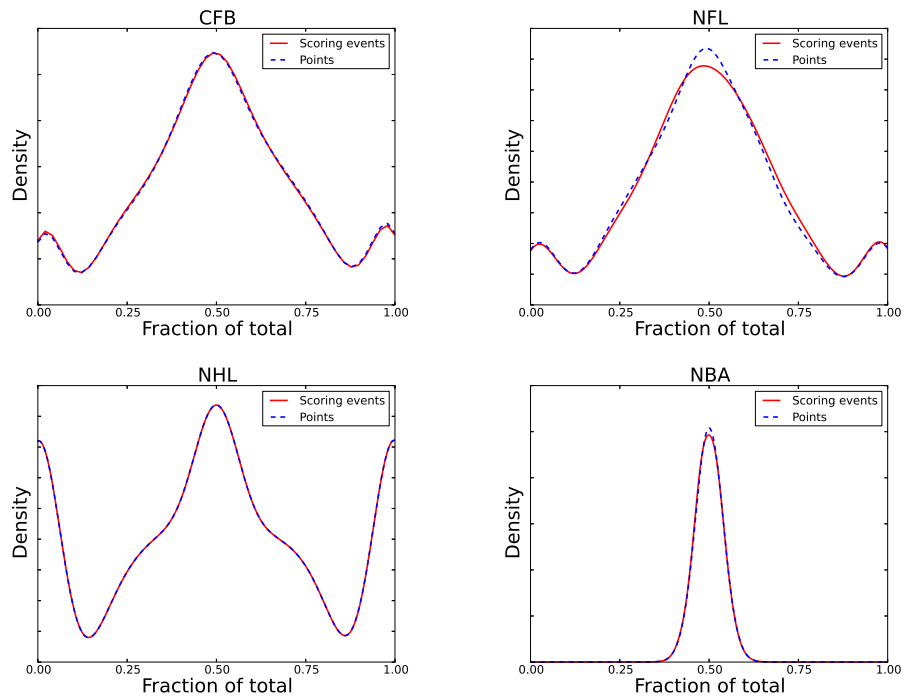


Figure S1: Smoothed distributions for the empirical fraction of total points won by a team (solid line), for each sport, plus the empirical fraction of total scoring events (dashed line; from Figure 4 in the main text). The very close agreement indicates that only very rarely does the point-value of scoring events—instead of simply their number—determine the outcome of a game.