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EVALUATING GOAL THREAT IN FOOTBALL USING PLAYER AND BALL LOCATIONS

VREDNOTENJE NEVARNOSTI GOLA V NOGOMETU Z UPORABO LOKACIJ IGRALCA IN ŽOGE

ABSTRACT

Goal scoring in football is relatively low but vitally important, hence research has considered how goals are created and scored with measures such as expected goals prevalent. The dynamical systems theoretical perspective, considers a collective system, such as football, as existing in two states, stable (no substantive advantage for either team) or unstable (advantage present). Hence, goal scoring events occur when the system has become unstable, with a "perturbation" the event causing the system state change. Here, a "goal threat" value was calculated every second (scaled from 0 to 100) using the XY coordinates of players and the ball, weighted in relation to proximity to the goal (a potential proxy for the degree of system instability). Video recordings and synchronised Amisco 2D representations of goals (n=64) scored in Swansea City AFC English Premier League 2012/2013 matches (n=20) were analysed using Dartfish v10 Pro software. Each goal was analysed from when the play was judged to be stable (no obvious goal scoring opportunity), or the start of possession, until the goal had been scored. Goals were not always preceded by high goal threat values (maximum goal threat values ranged from 13.4 to 99.0). The authors independently subjectively determined that perturbations occurred up to 7 seconds from when the goal threat value increased by at least 40%. Thus, perturbations were not directly related to goal scoring opportunities. This novel method provides a useful, quantifiable, and simple measure of goal threat that may also aid audience engagement and measure defensive effectiveness.

Keywords: player and ball locations, football, perturbations, dynamical systems

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IZVLEČEK

Zadetki v nogometu so ključnega pomena. Ker je le teh relativno malo, smo preučevali, kako se gol doseže. V ta namen smo uporabili koncept prevladovanja pričakovanih golov. Teoretična perspektiva dinamičnih sistemov je preučila nogomet kot kolektivni sistem, ki obstaja v dveh stanjih - stabilnem (brez prednosti za nobeno ekipo) ali nestabilnem (s prednostjo eni ekipi). Pri doseganju golov se sistemi spremenijo iz stabilnega v nestabilno stanje, pri čemer se "motnja" pojavi kot dogodek, ki povzroči spremembo stanja sistema. V raziskavi je bila izračunana vrednost "grožnje golu" za vsako sekundo, ki je upoštevala položaj igralcev in žoge ter oddaljenost od gola (kot približek za stopnjo nestabilnosti sistema). Za analizo je bilo uporabljenih 64 golov, doseženih na tekmah angleške Premier lige Swansea City AFC v sezoni 2012/2013, ki so bili predstavljeni v videoposnetkih in 2D animacijah programa Amisco. Vsak gol je bil analiziran od trenutka, ko je bila igra ocenjena kot stabilna, ali od trenutka, ko je ekipa pridobila posest žoge, do trenutka, ko je bil gol dosežen. Pred golom vrednosti grožnje niso bile vedno visoke, najvišje vrednosti so bile med 13,4 in 99,0. Ugotovili smo, da se je motnja običajno pojavila v roku 7 sekund od trenutka, ko se je vrednost grožnje povečala za vsaj 40% in da motnje niso nujno povezane s priložnostmi za gol. Ta nova metoda zagotavlja uporabno in merljivo merilo grožnje golu, kar lahko pomaga tudi pri angažiranju gledalcev in merjenju učinkovitosti obrambe.

Ključne besede: položaj igralca in žoge, nogomet, motnje, dinamični sistemi

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https://doi.org/10.52165/kinsi.29.3.26-48

INTRODUCTION

Football is a complex game due to the interaction of two teams of 11 cooperating players. The objective of the game is to simply score when in possession of the ball, or prevent goals being scored against the team when not. However, the method of success (i.e., scoring) exists in infinite ways. Research has tried to better understand these processes, although relatively obvious conclusions are common, such as determining that successful teams performed more goal scoring facets of play (e.g., Shot; Liu, Gomez, Lago-Penas & Sampaio, 2015). However, due to the unpredictable and low-scoring nature of football (Anzer & Bauer, 2021), superior performance on certain offensive metrics may not necessarily lead to more goals being scored, and therefore, match success (e.g., Crosses, Lago-Penas, Lago-Ballesteros, Dellal & Gomez, 2010). Hence, conclusions may simply reflect the data sample and not demonstrate indicator validity which can be widely adopted by teams of differing styles, competition levels, tactical principles, or the specific strengths and weaknesses of the players involved. However, recent efforts to discern these complex relationships in football have been investigated using XY coordinate data collected through player tracking systems (see Memmert, Lemmink & Sampaio, 2017; for a review) in conjunction with player event data.

Performance analysis research in football has often adopted a reductionist approach which considers isolated events or variables and assumes their analysis can lead to inferences regarding outcomes (Mackenzie & Cushion, 2013), sometimes leading to simplistic overviews of performance. Some research has utilised dimension reduction techniques like principal component analysis (Parmar, James, Hearne & Jones, 2018) which considers performances on groups of variables and how they can affect performance overall. Whilst these approaches can give meaningful insights, holistic assessment of performance is limited. An alternative approach, the dynamical systems theory (e.g., McGarry et al., 2002) which describes how behaviours fluctuate through a series of stable or unstable states (James, 2012) has been used to analyse sport performance, particularly in football (Davids, Araujo & Shuttleworth, 2005; McGarry, 2005; Duarte et al., 2013; Siegle & Lames, 2013; Fernandes et al., 2019; Clemente, Sarmento & Aquino, 2020). This approach considers the sequential dependency of different events whilst recognising that one action may result in relatively large changes to a whole system. By conceptualising football as a complex system, it allows the chaotic nature of the sport to be analysed (Low et al., 2020) whilst considering the interdependent behaviours of participants, determining how their complex interactions affect game outcome (Kim et al., 2019a). To conduct these types of analyses, player and ball tracking data is used (e.g., Frencken, de Poel, Visscher, & Lemmink, 2012; Vilar, Araujo, Davids & Bar-Yam, 2013; Memmert et al., 2017; Anzer & Bauer, 2021; Bauer & Anzer, 2021; Goes, Kempe, van Norel & Lemmink, 2021). For example, Memmert et al. (2017) explored team organisation using the distance to a positional centroid, speed of player movements and between player coordination using positional data. This dynamical system approach also utilised neural networks to analyse inter-team coordination, i.e., the variability of distances between the two teams' centroids before critical events such as goal scoring opportunities. It was suggested that these approaches could help objectify tactical performance consequently allowing coaches to modify training methods.

Vilar et al. (2013) analysed player interaction patterns (i.e., defensive stability and attacking opportunities) in different areas of the football pitch using 2D player displacement coordinates. For each frame, a net team numerical advantage or disadvantage was calculated, with the uncertainty of this computed using Shannon's entropy. The results indicated that both teams allocated more players to areas closest to their own goal line (consistent with a defensive strategy) and one team was more effective at maintaining a player overload when attacking and defending, despite both teams using a 4:3:3 formation. Since only one match was analysed, the extent to which team strategy differences are apparent and measurable remains a viable research question; consequently, such holistic dynamic system approaches appear more favourable compared to traditional reductionist methods. A further complication to the analysis of football lies in the fact that not all play is undertaken under the same conditions. Hewitt, Greenham and Norton (2016) presented the case for analysing football in the different moments of a match (i.e., established attack, offensive transition and set pieces) by virtue that defences are structured differently for each situation. Researchers have however already and regularly discriminated elaborate (established) attacks from counterattacks (offensive transitions; Tenga, Holme, Ronglan & Bahr, 2010a; Cerda et al., 2021). Factor analysis has been used to determine attacking and defending playing styles; for example, Fernandez-Navarro et al. (2016) used 19 action variables to identify six defining factors, including 1) direct or possession play, 2) crosses, 3) wide or narrow possessions, 4) fast or slow progressions, 5) pressure on wide or central areas and 6) low or high pressure exerted. This type of research has better contextualised the complexity of the attacking process in conjunction with defending since both play a part in determining how possessions progress.

Tenga, Holme, Ronglan and Bahr (2010b; 2010c) differentiated situations where the defensive organisation was described as balanced or imbalanced (i.e., situations where the defence was either in a relatively stable situation or not). Whilst the reliability for discriminating these situations was not provided, McGarry et al. (1999) demonstrated that expert squash coaches could reliably discern stable (i.e., no advantage) from unstable (i.e., one player is advantaged) situations. The transition point between these two different game states was labelled “perturbations”, however, robust universal definitions for these terms were not presented or agreed across wider literature (McGarry et al., 1999; Roddy, Lamb & Worsfold, 2014). The concept that important aspects of performance such as unstable situations could be delineated and analysed separately from stable situations, is intuitively sensible.

James et al. (2012) suggested that football could be considered relatively stable when the team in possession of the ball had no significant tactical or positional advantage over their opposition. The situation could then become unstable if a team created a goal scoring opportunity. Whilst there is logic to this distinction, defining a goal scoring opportunity was to some extent reliant on subjective opinion. More recently, Kim et al. (2019a) presented reliable and valid operational definitions for five unstable situations in football such as, penalty box possession, counterattack, ratio of attacking to defending players (RAD), successful cross and successful shot. Kim et al. (2019b) elaborated on this methodology and further distinguished an advantageous situation from the stable and unstable situations, suggesting three different states in football. The advantageous moments were suggested to occur immediately prior to a goal scoring opportunity but were not always present as a team could, for example, play a long ball from a stable situation to create an immediate unstable situation. The analysis suggested the RAD situation occurred the least frequently of all unstable situations but was the most effective. The main benefit of this analysis, however, is the recognition of different game states, which facilitates the identification of the important moments in a match which produce opportunities to create goal chances, shots, and goals. It may also be the case that identifying how individual teams create advantage and unstable situations may determine profiling characteristics of a team’s offensive strategy.

The difficulty in scoring goals is well known in football and hence there has been an abundance of research around this critical determinant of match outcome. For example, the probability of scoring reduces the further away from goal the shot is taken and scoring chances increase the closer to goal the ball is turned over (Tenga et al., 2010b). However, some of these findings are somewhat obvious and could be derived from a simple probability model assuming less distance to goal is advantageous. Link, Lang and Seidenschwarz (2016) tried to overcome this simplicity by creating a multifaceted “dangerousity” score by calculating the chance of a goal being scored on a video frame by frame basis using player and ball tracking data. The score was calculated from operationally defined measures related to the zone in which the player in possession of the ball was located and how much control of the ball was evident as this impacts the ability to implement a tactical decision. Further measures of pressure, the opportunity of the defending team to prevent actions on the ball, and density were used to calculate the evolving chance of a goal being scored. Whilst this method presents a reasonably accurate measure of the chance of scoring, termed dangerousity, it may also be labelled a measure of how unstable the situation was at each time point. The authors have presented a relatively complex solution to an interesting question but with this complexity comes reliability issues, particularly the relation to the subjective aspects of the analysis and the difficulty in replicating these methods. Given that other factors, such as the movement dynamics of the players, player direction, passing options, to name a few, were not measured, the application of the measure may be questioned.

Another metric, expected goals (the likelihood of a goal being scored in a given situation based on multiple similar past events, xG), is widely utilised in football demonstrating the probability a player will score a goal under the same in-game conditions (Anzer & Bauer, 2021). Such models by Opta (www.optasports.com) and Statsbomb (www.statsbomb.com) use several variables (e.g., distance to goal, shot angle, use of foot or head, one on one situation, open play, direct free kick, corner, long ball) to derive xG, however, the exact formulae is often not publicly available. This metric is deemed to identify players who perform better than their expected goals (high value strikers) and may also be added up per team to provide a description of team performance (Anzer & Bauer, 2021). Rathke (2017) tried to simplify the complex xG metric by incorporating just angle and distance of shot. Unsurprisingly, the model predicted actual goals better when both variables were used versus individually in isolation. Accuracy of such metrics will be improved by successively more complex models but there will be diminishing returns from increasing variable number. At some point the accuracy of the model will be fit for purpose and additional complexity will be unnecessary. In conclusion, measures related to goal scoring, whether over time or at the time of a shot have undeniable value, even if only from a consumer of football perspective.

The aim of this study is to present an alternative to the measure of dangerousity (or instability), termed the “goal threat” metric. Since goal threats have not been operationally defined, but theoretically occur at or around transitions between different system states. A secondary aim will be to compare raters’ subjective assessments of when unstable situations occurred. This will attempt to ascertain whether these instances are consciously observed at, or around, the peak goal threat values or during sudden elevations in the goal threat metric.

METHODS

Data Collection

Quota sampling was used to select video recordings and synchronised Amisco (Nice, France) 2D representations of goals (n=64) scored in Swansea City AFC EPL 2012/2013 matches (n=20). Goals were categorised into one of either involving a mistake by a defender (n=6), initiated by a set piece (n=18), the attack originated by a long pass of over 60m (n=4), the shot was from outside the penalty area (n=5), the critical pass or dribble originated from near the touchline (n=14), or the critical pass or dribble originated from the central area of the pitch (n=17). These categories were not mutually exclusive as for example a set piece could involve a mistake by a defender. Priority for categorisation was the order as presented above. Clips were edited to start at the beginning of the possession for the team that scored or when the most recent stable situation occurred (McGarry et al., 1999; James et al., 2012). Ethical approval for the study (A1:215) was granted by a university's ethics committee.

Procedure

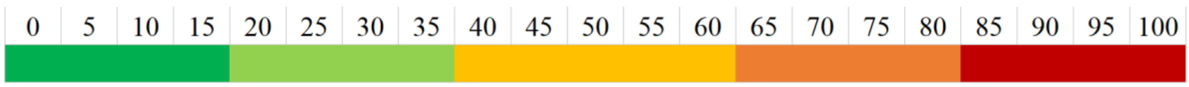
The Amisco 2D representations of the goals were viewed in Dartfish v10 pro (Fribourg, Switzerland). Still images (n=699) were captured every second up to the point at which the goal was scored, hence the number of frames (still image) varied for each goal (minimum 3 images). Each image was loaded into the Windows Paint program and cropped to show just the pitch with side-lines and resized (500x323 pixels). This procedure ensured equal pitch dimensions for the different match venues used. The mouse pointer was placed over the centre of each player and the ball sequentially and the XY coordinate of each recorded in Excel.

The calculation of the "goal threat" value

The goal threat value was quantified using player and ball locations through an automated Excel spreadsheet which allowed the derivation of the formula and the individual weightings to be tested repeatedly until a satisfactory model was completed.

The aim was to produce a goal threat value where a totally (if such a situation exists) stable state (no goal scoring threat) would have a zero value and a totally unstable state (goal certain to be scored) would have a value of 100 (Figure 1). Values were selected for ease of interpretation (0 to 100 scale and shading for visual aid) and approximately related to the probability of scoring a goal in a given situation e.g. greater chance of scoring against an unorganised defence compared to organised (Tenga et al., 2010a), regaining possession further up the pitch progressively more likely to result in a goal (Tenga et al., 2010a; Tenga et al., 2010b), shooting from in front and closer to the goal more likely to score than further away and wider angles (Yiannakos & Armatas, 2006; Wright et al., 2011; Gómez et al., 2012; Michailidis et al., 2013) and counter attacks more productive than elaborate attacks (Tenga et al., 2010a, Tenga et al., 2010b). These factors resulted in players and ball pitch locations, number of effective defenders (in line with the ball or between the ball and the goal) and the ratio of attackers to defenders as the major influences used to derive the probability of scoring a goal. The definition of possession used did not involve a change of possession when a defender touched the ball but did not gain control of the ball (Jones, James & Mellalieu, 2004).

Figure 1. The goal threat value continuum.



Player and ball location values

The player and ball XY coordinates were located into one of 340 cells (20x17) using a lookup function in Excel. The number of cells and the values associated with each cell was finalised after reliability testing (16 randomly selected images processed twice) used to ensure acceptable accuracy (98.64% agreement using the percentage error equation from Hughes, Cooper & Nevill, 2002). Three heat maps were produced for the left to right direction of play (team in possession of the ball, defending team and ball) and mirror image maps used for right to left play. The heat map for the team in possession of the ball (Figure 2) illustrates that a player becomes more dangerous in relation to creating scoring opportunities in areas closer to the goal and towards the middle of the pitch (Horn, Williams & Ensum, 2002).

Figure 2. Player values for team in possession ($TIP_{v1..11}$) of the ball attacking the right goal.

0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.8	0.8	0.7
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.8	0.87	0.88	0.87
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.86	0.88	0.92	0.87
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.75	0.73	0.87	0.93	0.93	0.92
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.87	0.93	0.95	0.95
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.88	0.94	0.95	0.96
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.8	0.88	0.94	0.96	1
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.88	0.94	0.95	0.96
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.87	0.93	0.95	0.95
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.75	0.73	0.87	0.93	0.93	0.92
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.86	0.88	0.92	0.87
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.8	0.87	0.88	0.87
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.8	0.8	0.7
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68

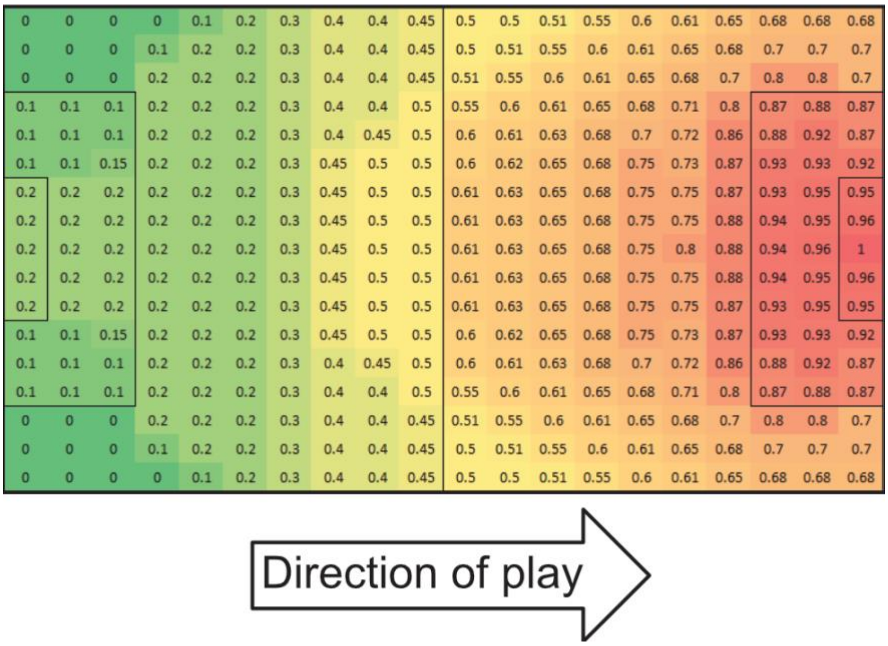
The defending team heat map (Figure 3) was based on the same logic as Figure 2 except that the extant literature (e.g., Tenga et al., 2010a) and pilot testing suggested that when defenders were located in their own penalty area their proximity to the goal reduced the threat of a goal being scored and hence lowered the goal threat value in comparison to being outside the penalty area.

Figure 3. Player values for team defending the right goal ($DT_{v1..11}$).

0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7	0.7
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.72	0.68	0.68	0.68
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.73	0.65	0.65	0.65
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.72	0.73	0.75	0.62	0.62	0.62
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.72	0.75	0.78	0.6	0.6	0.6
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.72	0.75	0.78	0.6	0.5	0.5
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.72	0.75	0.78	0.6	0.5	0.4
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.72	0.75	0.78	0.6	0.5	0.5
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.72	0.75	0.78	0.6	0.6	0.6
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.72	0.73	0.75	0.62	0.62	0.62
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.73	0.65	0.65	0.65
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.72	0.68	0.68	0.68
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7	0.7
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68

The ball heat map (Figure 4) followed the same logic except that the degree of goal threat increased more distinctly as the ball entered the defending penalty area due to the increased likelihood of a shot or penalty being conceded.

Figure 4. Ball value (B_{v1}) when the right goal is being attacked.

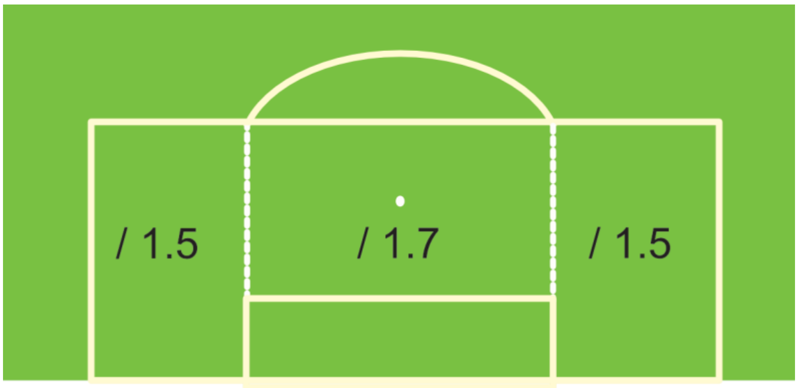


0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.8	0.8	0.7
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.8	0.87	0.88	0.87
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.86	0.88	0.92	0.87
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.75	0.73	0.87	0.93	0.93	0.92
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.87	0.93	0.95	0.95
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.88	0.94	0.95	0.96
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.8	0.88	0.94	0.96	1
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.88	0.94	0.95	0.96
0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.61	0.63	0.65	0.68	0.75	0.75	0.87	0.93	0.95	0.95
0.1	0.1	0.15	0.2	0.2	0.2	0.3	0.45	0.5	0.5	0.6	0.62	0.65	0.68	0.75	0.73	0.87	0.93	0.93	0.92
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.45	0.5	0.6	0.61	0.63	0.68	0.7	0.72	0.86	0.88	0.92	0.87
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.55	0.6	0.61	0.65	0.68	0.71	0.8	0.87	0.88	0.87
0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.45	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.8	0.8	0.7
0	0	0	0.1	0.2	0.2	0.3	0.4	0.4	0.45	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.7	0.7	0.7
0	0	0	0	0.1	0.2	0.3	0.4	0.4	0.45	0.5	0.5	0.51	0.55	0.6	0.61	0.65	0.68	0.68	0.68

Attackers relative to defenders

Pilot testing with reference to the work of Kim et al. (2019b) supported the view that an important variable in relation to the success of an attack was the number of attackers relative to the number of defenders, particularly when the ball was in the penalty area. To factor this into the goal threat value calculation player locations in relation to the position of the ball (X coordinate) were needed. Consequently, only players in line (parallel to the goal line and same X coordinate) and nearer to the goal were included in this calculation. To ensure the ball carrier was always included in this calculation his X Y coordinate was always input as the XY coordinate of the ball. This always included the defending goalkeeper which meant the defence typically had a numerical advantage (this is typical in football e.g., see Vilar et al., 2013). The goal threat value for the attackers relative to defenders (ARD) was the number of attackers (A_n) divided by the number of defenders (D_n). However, when the player in possession of the ball was inside the penalty area, the effect of the defenders could increase the goal threat value due to them blocking the view of the goalkeeper. To adjust for this the goal threat value was divided by the values in Figure 5 based on the position of the ball carrier ($\frac{\frac{A_n}{D_n}}{1.5}$ or $\frac{\frac{A_n}{D_n}}{1.7}$).

Figure 5. Adjustment values for attackers relative to defenders (ARD) calculation when ball carrier was inside the penalty area.



There were some instances when the number of attackers eligible for this calculation was zero resulting in a zero goal threat value. For example, if a player shot and the goalkeeper saved the ball at the time point used for the calculation. No adjustment was made for this event. A similar problem existed for corner kicks as the location of the players could result in this calculation considering the situation the same as a one on one with the goalkeeper (unrealistically high goal threat value). The solution for this specific situation was to consider the number of attackers and defenders inside the penalty area for the ARD calculation.

The goal threat value formula

The formula used the three values (player locations, ball location, attackers relative to defenders) such that the value denoted the degree of goal threat (higher value equals greater goal threat) with a high positive value meaning that the team in possession was creating the goal scoring opportunity:

$$GT = 100 * \frac{\left(\frac{\sum_{i=1}^{11} TIP_i}{\sum_{i=1}^{11} DT_i}\right) * (B_{v1}) * (ARD)}{2}$$

Key: TIP: player value for Team in possession; DT: player value for defending team; B: ball value; ARD: attackers relative to defenders' value

If any players had been sent off (red card) or were injured and hence not participating, they were given a nominal fixed value (0.01) to ensure the calculations did not produce abnormal values. Similarly, a player taking a throw-in was given an XY coordinate on the boundary of the pitch.

Subjective definition of when unstable situations occurred

The authors independently viewed the video clips to determine at what point in time they thought the initial stable situation became unstable (referred to as a perturbation). Each followed the procedures used in previous studies (Kim et al., 2019a; Kim et al., 2019b) judging when a stable rhythm of play (i.e., no significant advantage to either team) changed due to pitch location, game situation or a specific action (Kim et al., 2019b) which put the opponent under a significant disadvantage (i.e., an unstable situation became apparent; James et al., 2012). The moment an unstable situation arose was chosen as the critical time point, as opposed to determining perturbations, as this had been shown to be both reliable and valid (Kim et al., 2019a). Whilst the explanation for the onset of an unstable situation occurring has been deemed to be a perturbation (McGarry et al., 1999) no consensus opinion has been forthcoming as to what this entails in football. Furthermore, if, for example, a pass to a striker was considered a perturbation, then some debate could ensue as to the point in time the perturbation took place (i.e., when the ball was kicked or received). By using the onset of an unstable situation, the time frame was more straightforward, in the case of the pass it would be when the striker received the ball. Where there were differences in opinion in locating the unstable situation, they were resolved through discussion, so that a single point could be entered on the graphs produced for the results section.

Limitations of the goal threat value

The Goal Threat calculation did not differentiate player positions in great detail. For example, a defender between the ball and the goal has more of an effect in preventing a shot from going in than a defender in a similar position but not in line with the goal. Similarly, a defender marking an attacker could be in close proximity but of varying effectiveness depending on the exact position. These were not accounted for in the calculations. The calculation also did not differentiate a player with the ball travelling backwards or forwards within a cell, probably more of a weakness when the player with the ball is around the penalty area. Similarly, the model did not distinguish between player abilities (e.g., Messi is likely to be more dangerous just outside the penalty box than most other footballers). An offside player's value was used in the calculation even though the rules state that if he interferes with play the referee should stop play and penalise the player. Finally, the zero-value recorded if the calculation was made at the point in time when a player's shot had been saved by the goalkeeper was an unrealistic goal threat value because, if the ball was not held, there could easily be a rebound and a likely goal scoring situation.

RESULTS

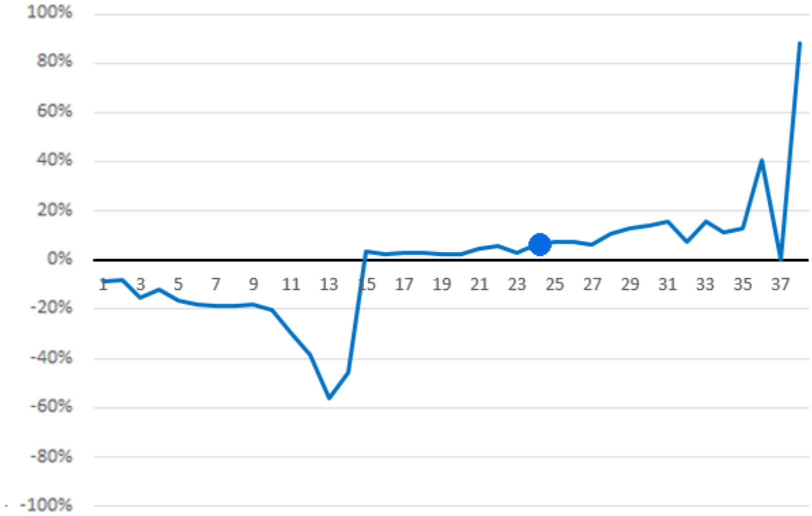
The edited video clips of the goals lasted an average of 10.9 seconds consisting of a range between 3 and 38 still images. The maximum goal threat values for each type of goal varied considerably with the lowest and highest maximum values shown in Table 1.

Table 1. Maximum goal threat values for each goal category.

Goal categories	Maximum Goal Threat values	
	Lowest	Highest
Middle (n=17)	13.44 %	94.64 %
Wide (n=14)	24.69 %	99.00 %
Shot from outside penalty area (n=5)	25.99 %	66.28 %
Long ball (n=4)	49.54 %	72.50 %
Set Piece (n=18)	15.79 %	99.00 %
Mistake (n=6)	18.84 %	93.34 %

Since goal threat values were calculated with respect to the team in possession positive values represented possession by the team who scored the goal whereas negative values represented possession by the opposition (Figure 6). In this case the team that scored the goal turned an opposition attack into a goal by turning over the ball at frame 15 and counter attacked to score. The authors' subjective account of where a perturbation occurred is shown as the blue dot, 9 seconds later at frame 24 (Figure 6). The zero-goal threat value at frame 37 was an example of the limitation of the calculation due to the player's shot having been saved by the goalkeeper. On this occasion the save rebounded to an attacker who scored.

Figure 6. An example plot of the goal threat value involving a turnover in possession.

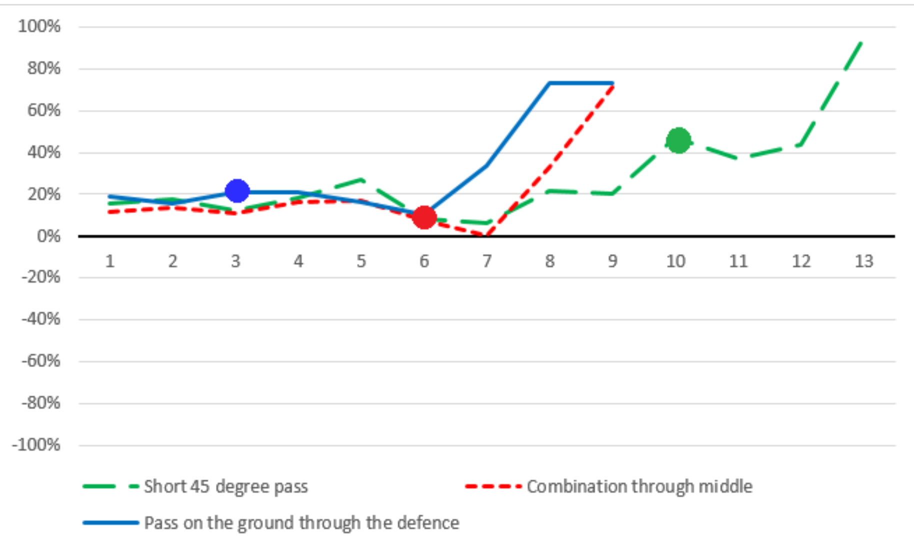


Since this is a relatively small-scale analysis of goals, primarily to test the veracity of the goal threat value as a tool to facilitate football analysis, a selection of goals, based on their *a priori* categories, will be presented as exemplars rather than suggestive of trends.

Goals scored through the middle

These clips tended to start with a goal threat value around 15% as the goal scoring team had possession of the ball throughout the edited clip. Note that clips were edited to start at a point when the authors agreed that the game was subjectively stable. The three goals selected (Figure 7) show a tendency for the goal threat value to remain fairly constant before increasing prior to the goal being scored (corresponding to the ball entering the penalty area). Author derived onset of unstable situations occurred 3 to 6 seconds before the ball went into the net.

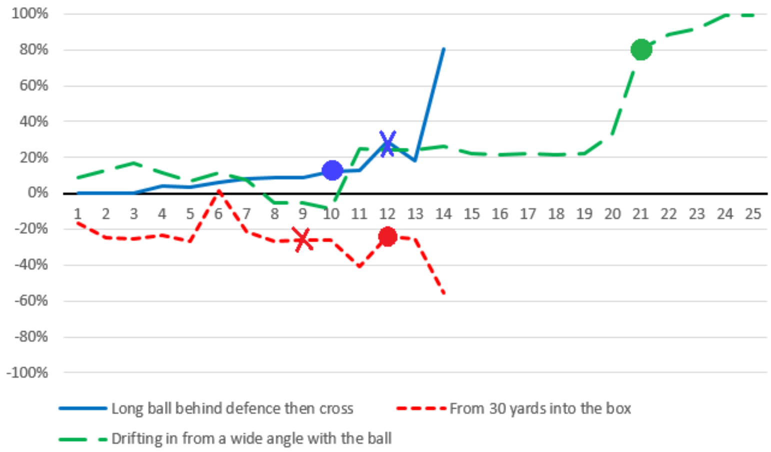
Figure 7. Three examples of goals scored through the middle.



Goals scored from out wide

Like the previous category these exemplar goals (Figure 8) typically involved a period of low fluctuation of relatively low goal threat values (between 0 and 30%) followed by a sudden increase (to between 60 and 99%). Onset of unstable situations were identified as occurring up to 4 seconds prior to the goal being scored.

Figure 8. Three examples of goals scored from out wide.

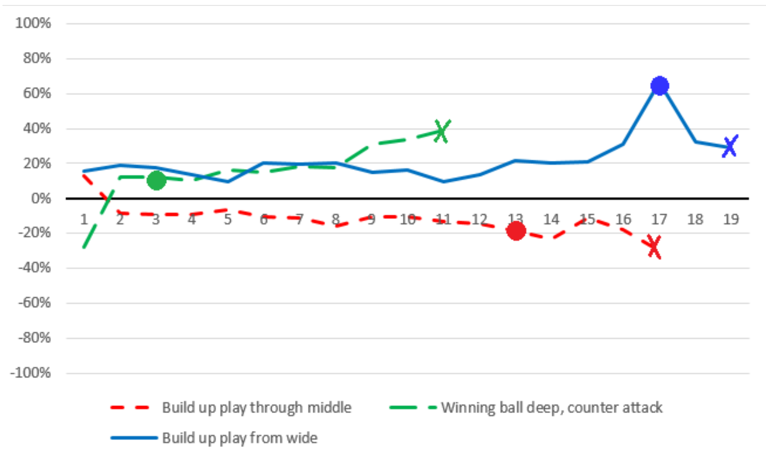


Note: X denotes when the cross was played

Goals scored by shots from outside the penalty area

These clips were characterised by less dramatic increases in goal threat values (between 30 and 60) around the goal being scored in comparison to goals scored through the middle and from out wide (Figure 9). The onset of unstable situations identified for these clips included one that occurred 8 seconds before the goal was scored.

Figure 9. Three examples of goals scored from a shot taken outside the penalty area.



Note: X denotes when the shot was taken

Goals scored involving a long ball (over 60m)

The goals involving a long ball did not exhibit an obvious pattern because of the variability in what happended following the long ball (Figure 10). Onset of unstable situations were deemed to follow the long ball by 4 to 6 seconds.

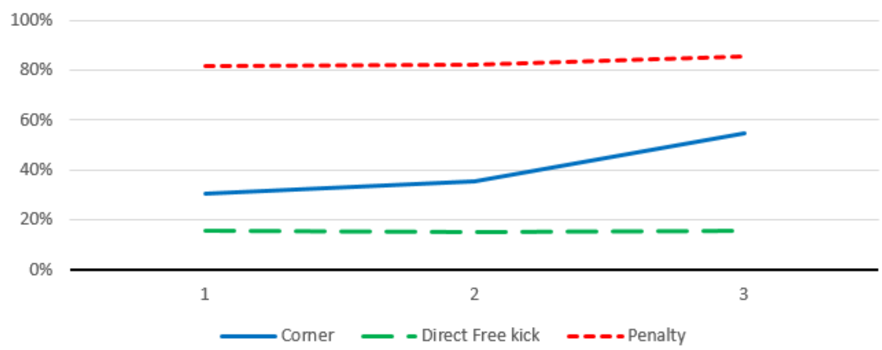
Figure 10. Three examples of goals scored involving a long ball.

Note: X denotes when the long ball was played

Goals scored from a set piece

When a goal was scored directly, within 3 seconds of a set piece, the goal threat value remained fairly constant because the player positions did not change very much (Figure 11) and onset of unstable situations were not identified.

Figure 11. Three examples of goals scored directly, within less than three seconds, from set pieces.



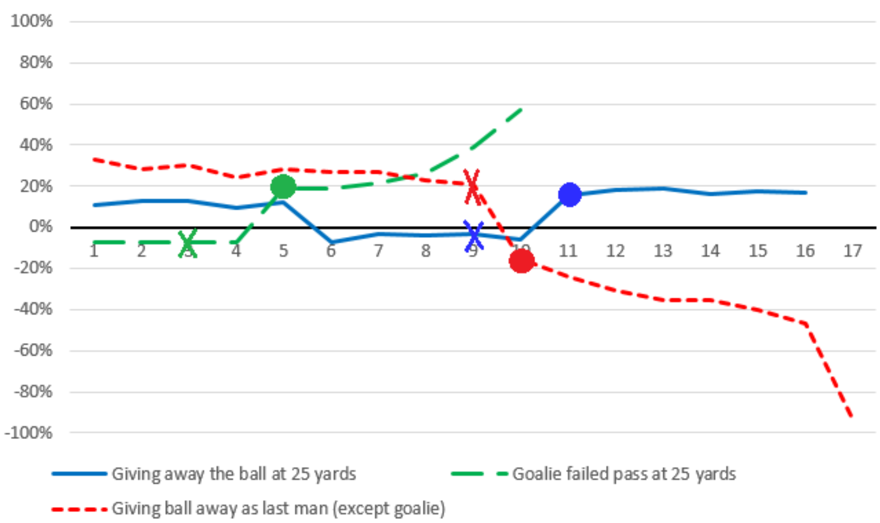
When set pieces lasted longer than 3 seconds the initial threat had been averted and the subsequent plot was less a consequence of the set piece itself but more related to the player positions and intervening play (Figure 12). Each of these goals were preceeded by an onset of an unstable situation, but unrelated to the original set piece.

Figure 12. Three examples of goals scored from set pieces lasting longer that 3 seconds.

Goals scored following a mistake by an opponent

In these examples, when the opponent made a mistake, possession changed, and the authors deemed the onset of unstable situations occurred within 2 seconds of the mistake (Figure 13). Goals were scored up to 8 seconds after the mistake but could still be attributed to the mistake.

Figure 13. Three examples of goals scored following a mistake by an opponent.



Note: X denotes when the mistake was made

DISCUSSION

This paper recreated the "dangerousity" score (Link, Lang and Seidenschwarz, 2016) using a much simpler model that could easily be calculated live for, amongst other things, a potential improvement in audience engagement, be that in a viewing or betting context. For this to be useful, the goal threat value should correlate to the probability of scoring, although given the multitude of reasons why goals are not scored in potentially very good opportunities, the possibility of any value being totally accurate is impossible. However, since the calculation of goal threat primarily concerned the proximity of players and ball to the goal, the value certainly rose as the possibility of a goal being scored rose.

Hewitt et al. (2016) had identified that attacking football exists in three quite different scenarios. A set piece that is taken relatively close to the opponent's goal results in very specific defensive and/or attacking formations that are unique to the situation and to the teams who can practice set moves for these situations. Counterattacks are fast evolving situations where the ball in turned over resulting in the team that was defending very quickly attacking their opponents who are set up for attack not defence. The final and most common situation is where the team in possession of the ball plays the ball forward against an opponent who is set up to defend. This scenario can involve lots of different methods by which the attacking team tries to get the ball past the opponent's defensive line e.g., passing out wide for a cross into the box. Given this large number of possible attacking methods this study utilised six specific scenarios to assess how the goal threat evolved within a sample of these specific situations. Hence a defender making a mistake allowed a counterattack. The set piece scenario was sampled along with four specific scenarios that involved a team trying to break the opponent's defensive line. The initial finding was that the maximum goal threat values, for the six different goal scoring situations, ranged from as low as 13.44% (critical pass from middle of the pitch) to 99% (set piece and critical pass from wide area of the pitch). Indeed, even within each category large variations in goal threat occurred. This finding tends to support the notion that the complexity of football results in a myriad of different passages of play, which we know infrequently lead to goals. Interestingly, even when attacks were grouped for similarity, they evolved in markedly different ways in terms of the development of a goal threat, due to the difference in how the defenders and attackers moved to try to gain territorial advantage. The data collected regarding where the onset of an unstable situation occurred clearly showed that this moment was unrelated to the goal threat value as these values ranged between 5 and 80%. In other words, the actions responsible for changing the situation could occur at any point in time, in any position on the pitch and either immediately prior to the goal scoring opportunity or some time before.

The six different scenarios sampled in this study were selected to try to test the range of possible ways that goal scoring situations develop from the start of possession. Unsurprisingly then, they presented very different profiles for goal threat values. For example, goals scored from play originating in the middle and wide areas of the pitch tended to start in a stable situation with low goal threat values and the defending team in a balanced (organised) situation (Tenga et al., 2010b; 2010c). The goal threat value then increased as the ball entered the penalty area because of player and ball values increasing. The onset of the unstable situation tended to be 3 to 6 seconds prior to the goal being scored but could have occurred before or after the decisive pass.

In the long pass, mistakes by defenders and goals scored over 3 seconds after a set piece samples, goal threat value profiles differed markedly due to the large variation in how the possession progressed. However, it seems that the long ball or the defender mistake led to the onset of the unstable situation (in this sample) which then either directly or not led to the goal scoring opportunity. Similarly, in the set piece situations where over 3 seconds of play followed the set piece, it seems that the onset of an unstable situation preceded the goal scoring opportunity. Collectively, these scenarios tend to suggest that critical events such as a long ball have the possibility of creating an unstable situation. This may not always going to be the case, but even if it does occur, the possibility of a goal scoring opportunity is not a given. This helps to explain why football is such as low scoring game as it seems that the defending team has multiple opportunities to prevent the goal scoring opportunity. This data also supports the view of Kim et al. (2019b) who suggested three different states in football, distinguishing an advantageous situation from the stable and unstable situations. Here we described the onset of an unstable situation which tended to precede a goal scoring opportunity. Whilst the terminology and timelines for these events may be different between the studies the consensus opinion seems to suggest that we can break the attacking process down into various events which may or may not exist in any given attack. Each of these events may help teams to identify players who are responsible for attacking or defending each of these specific moments of play. Similarly, how teams set up their attacking and defending positions would have ramifications to the success or failure of each of these events.

The final two situations sampled, shots from outside the penalty box and set pieces where the goal was scored almost immediately, were thought to be very different scenarios to the other situations. Goals scored from outside the penalty area were situations where it was hypothesised that an unstable situation may not have existed before the shot. For example, a player in possession of the ball with defenders between the ball and the goal may be considered a relatively stable situation. However, a sudden and exceptional strike of the ball could end up being a goal with the shot itself considered the onset of the unstable situation. The sampled goals in this situation tended to have low goal threat values (less than 40%) and, in one case the onset of an unstable situation occurred 8 seconds prior to the shot. In another situation the onset of the unstable situation did occur just prior to the shot. The obvious inference here is that the onset of an unstable situation is likely to occur in possessions that result in a goal being scored but it is not a prerequisite and shots may infrequently occur in relatively stable situations. This contrasts to the goals resulting from a set piece where the authors did not indicate the onset of an unstable situation. However, it could be argued that the situation itself was an unstable situation, most definitely in the case of a penalty kick. Hence a direct shot from a free kick outside the box or a corner kick aimed into the penalty box may be considered unstable situations, a view supported by elite teams who practice these specific situations using various playing positions and movement patterns to maximise their chance of scoring, and defending, these goal scoring opportunities.

This approach to tracking the evolution of each possession may allow a simple comparison between teams in terms of their relative success, both for attacking and defending, the different situations. It has also clearly shown that a single attacking possession may contain a decisive event that leads to the onset of an unstable situation and a goal scoring opportunity is not necessarily related directly to this event. At each stage of the possession there is a chance of failure and it is because of this goal scoring events are infrequent. Another way of presenting this is to suggest that football teams are very good at defending. Of course this is not surprising given that teams try to maintain an extra defender to the number of attackers and there is a goalkeeper to further reduce the probability of a goal being scored. These factors were hence built into the model of goal threat although the actual model derived values were not presented as precise values rather indicative of scoring possibility. The clear inference regarding this approach is the realisation that coaching strategy should consider methods to instigate/prevent the onset of unstable situations with the recognition that this is not always the precursor to a goal scoring opportunity. For example, long balls, short passes, or dribbles beyond or to the defensive line can all result in the onset of an unstable situation. From an attacking perspective the realisation that this is the beginning of the attacking process, where the defence usually has an advantage, should determine the critical strategy of how to best progress this situation i.e., where should the support players be? From the defending perspective, the onset of an unstable situation requires good defensive coordination to prevent the situation becoming a goal scoring opportunity. An evaluation of these situations should help determine the defensive balance of a team, assessed in the different situations to provide evidence of strengths but more importantly weaknesses in any situation.

The onset of unstable situations occurred up to 7 seconds before the goal was scored and during this time a marked change (at least 40%) in goal threat value was often seen. This suggests that whilst a perturbation may have contributed to the onset of an unstable situation it was often the case that other events occurred which contributed to the onset of the goal scoring opportunity. It is unknown at this stage what these events are, whether they should be labelled perturbations, and whether the situations described here match those events labelled by Kim et al. (2019b). Future studies are required to further consider the attacking process, particularly in open play situations, to determine how teams create the goal scoring opportunities. It may be the case that studies looking at other sports may be useful in helping to categorise the attacking process. For example, in rugby union possession is considered in terms of phases whereby when the forward momentum is stopped due to a ruck forming, the possession is deemed to start a new phase. In football this approach could be utilised if one considers a failed attempt to create an unstable situation as being the end of a possession phase, thus if the team retains possession, then a second phase begins as the team tries again to create an unstable situation.

CONCLUSION

The use of a formula to calculate an evolving goal threat value, using player and ball locations and the number of attackers relative to defenders, allowed visual representations of the moments preceding goals being scored. These plots emphasised the variability associated with the evolving goal threat for six different goal scoring situations sampled from one EPL team over a season. The authors also identified when the onset of an unstable situation occurred, defined as the onset of the opponent being at a significant disadvantage. The comparison of these two measures led to the conclusion that the onset of an unstable situation was not directly related to goal scoring opportunities as the timing of these events varied a lot between the sampled goals. The onset of an unstable situation sometimes meant that a goal scoring opportunity was immediate, although sometimes it was not (contrary to the views of James et al., 2012). This agrees with Kim et al.'s (2019b) suggestion that three different states occur in football. We suggest that the label "advantageous" (Kim et al., 2019b) be changed to "unstable situation without an immediate goal scoring opportunity" to reflect the belief that this situation is deemed to be unstable. Determining precisely when this interaction caused a disruption in the goal threat values may be impossible as different interactions may produce different system reactions. Future research should try to improve the model in the ways suggested and assess whether different weightings are needed for different actions (e.g., Should a dummy run be considered the same threat as beating a player with the ball). If this technique could be undertaken live, using live player tracking of XY coordinates, there is the potential for this to be a useful tool for coaches, television broadcasters and the betting industry coverage of football matches.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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