Developments in Performance Analysis in Football and their Influence on the Coaching Process

Applied Football Match Analysis Assignment

Name: Connor Hayes

Email: Connorhayes.shu@gmail.com

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Introduction

Performance Analysis in Sport

At its core, performance analysis in sport is the process of advancing understanding of game behaviour to improve future outcomes (McGarry, 2009). According to Hughes (2007), performance analysis is the process of recording performance in order to quantify critical events in a consistent and reliable manner. The application of performance analysis in sport includes tactical and technical evaluation, as well as database analysis and modelling (Hughes, 2007).

Objectivity and an Evidence-Based Coaching Approach

It is widely accepted that performance analysis is an integral part of the coaching process in sports (Mackenzie, 2013). Employing performance analysis significantly improves objectivity in the coaching process by allowing for 100% recall of critical events. Without performance analysis, coaches may be unable to accurately recall critical events for a variety of psychological reasons, including recency bias (Baddeley, 1993), emotional responses (Fletcher, 2010), and confirmation bias (Nickerson, 1998). Employing performance analysis provides coaches with historical performance data which can be used to make more objective and informed decisions. The rise of performance analysis has supported coaches in applying an evidence-based coaching approach in sport. In this report, I will describe two current developments in performance analysis in Football and their significance on the coaching process.

Neuroscience in Football

Cortical Activation in Sport

Much of the academic research surrounding neuroscience in sport stems from the neural efficiency hypothesis which proposes that more intelligent individuals exhibit lower cortical activation when performing a cognitive task (Dunst, 2014). Academics such as Hatfield (2020), Grabner (2006), and Babiloni (2010) have demonstrated that the neural efficiency hypothesis extends to individuals performing motor skills in sport. Their findings support the psychomotor efficiency hypothesis (Hatfield, 2001), which states that, when performing the same skill in a sport, professional athletes exhibit lower cortical activation than novices.

The most common technique neuroscientists have employed to assess cortical activation in athletes is Electroencephalography (EEG). EEG is a useful tool for recording fluctuations in the electrical activity of the brain through electrodes attached to the scalp (Holmes, 2017). The non-invasive and portable nature of EEG makes it suitable for capturing brain activity during sporting movements outside of a laboratory setting. By employing EEG, a number of studies (Di Russo, 2005; Hatta, 2009; Wright, 2012) have demonstrated that athletes display a lower amplitude and a later onset of Movement Related Cortical Potential (MRCP) before performing a motor task which they have mastered (Kujawski, 2016).

F.C. Copenhagen Academy: Neuroscience in Player Development

F.C. Copenhagen appointed Jes Buster Madsen as the club's first Head of Research & Development in August 2021, establishing a long-term strategy for integrating neuroscience in player development. Starting from the ground-up, Madsen aimed to understand the different brain processes that underline a player's actions and, as a result, determine which types of cognitive capacities are associated with success in football. Madsen (2023) emphasises that the role of neuroscience in football should not look to define a player's game intelligence. Instead, he argues that neuroscience should describe and measure the cognitive prerequisites for making quality decisions on the pitch. Therefore, rather than analysing the outcome of players decision making, Madsen analyses the players cognitive and perceptual capacities which influences their decisions (Madsen, 2023).

To measure the cognitive and perceptual capacities of F.C. Copenhagen Academy players, Madsen developed a virtual-reality cognitive assessment tool with fourteen different measurable abilities (Training Ground Guru, 2023). The different measurements gives a cognitive profile of a player, including abilities such as scanning, working memory, pattern recognition and attention. In a podcast with Training Ground Guru (2023), Madsen discusses how a player's cognitive profile can help coaches understand why a player may struggle when playing a different role or position. As a result, analysing a player's cognitive profile can help F.C. Copenhagen Academy coaches in producing well-balanced players who can play across the pitch. The ability to play in multiple positions is essential for players in the

modern game, since many elite-teams adopt structural fluidity to gain positional advantages in different phases of the game (Modern Football Analyst, 2020).

Madsen has had a substantial impact on the coaching process at the F.C. Copenhagen Academy. Madsen (2023) reports that the coaches underwent a year of lectures on various aspects of neuroscience and spent a further six months developing football coaching exercises incorporating cognitive elements (Training Ground Guru, 2023). One of the first basic principles of neuroscience which Madsen looked to implement was the impact of ecological psychology on players perception in training. Ecological psychology presents human behaviour as radically situational and heavily dependent on a person's environment (Barker, 1968). Applying this concept, Madsen argues that to improve a player's perceptional system, training exercises must have the same specifications, physically and psychologically, as a game scenario. By analysing the behaviour of coaches and players in training, the F.C. Copenhagen Academy were able to test and create training exercises which were more game-realistic. Madsen also confirmed that the language and the way the coaches communicate to players has been adapted. This follows Madsen's analysis that traditional arrows on a tactics board is less effective when discussing tactics with players. Instead, Madsen identified that the implementation of tactical instructions is more effective when coaches help players visualise bodily movements that allow for the tactical change (Training Ground Guru, 2023).

Liverpool F.C.: Neurofeedback in Set-Piece Training

Since August 2021, Dr. Niklas Häusler has been working with players at Liverpool F.C. to improve set-piece precision by reaching their optimal mental state (The Athletic, 2021). Häusler identified neuroscience research that was transferable to football after he recognised how neuroscience in sport primarily focused on precision sports such as archery, darts and golf. Häusler developed training exercises to improve a football player's ability to control their mental state, regardless of external factors such as high-pressure scenarios or fatigue. In an interview with The Athletic, Häusler discussed his methods and alluded to the concept of the flow state. Häusler (2021) explains how a player's brain state, such as being more relaxed or more agitated, can be sub-optimal for them to "get in the zone".

Mihaly Csikszentmihalyi (2013) conceptualised 'flow' as a state of deep concentration, complete absorption in an activity, a distorted sense of time, and a sense of intrinsic reward. Applying the flow state theory, Häusler's exercises and analysis assist players in identifying and focusing on thoughts or processes that enable them to engage in an optimal state of mind to achieve high-level performance (Häusler, 2021). Although Häusler has not disclosed his methodology, his process involves attaching electrodes to a player's head to measure brain states. Therefore, it is likely that Häusler incorporates EEG in neurofeedback training with Liverpool F.C. players to assess and enhance cognitive functions during set-pieces. Häusler's one-to-one coaching centred on brain activation analysis has cultivated Liverpool's set-piece training. Although the training is a supplementary component of Jurgen Klopp's

training program, Liverpool have won all four of their penalty shootouts since the club have integrated neuroscience in their set-piece training.

Neuroscience and the Coaching Process

Due to the primitive nature of neuroscience in football, there is limited insight into the application of neuroscience to improve performance. However, combining research and practical experience from Dr. Niklas Häusler and Jes Buster Madsen can illustrate the massive potential for neurofeedback practices in player development. Neuroscience can significantly improve the coaching process by supporting coaches in identifying and developing more effective training exercises that replicate players in-game perceptions and cognitive activity.

Other Applications of Neuroscience in Football

Another area of football where neuroscience can improve performance is refereeing. Zhang (2022) employed EEG to research the influence of home advantage on the decision-making of referees in football. The study found that less experienced referees triggered a greater response to error-related negativity (ERN) and tended to reduce unfavourable calls against the home team. This demonstrates the potential of neurofeedback in training non-biased refereeing decisions.

Multiple Object Tracking

Tracking Technology in Sport

Multiple Object Tracking is a complex computer vision technology, that can be used to assess the interactions, positions, and movements of players in sports. A number of techniques for tracking sports players have been researched, such as Tracking-Learning-Detection (Kalal, 2011), Boosting (Z. Hong, 2015), and Discriminative Correlation Filter with Channel and Spatial Reliability (Lukezic, 2017). However, deep learning using Convolutional Neural Networks, such as YOLOv2, has most notably improved the practicality and accuracy of tracking players in team sports. Dr. Manuel Stein further enhanced deep learning detection and tracking, by integrating real-time skeleton extraction of sports players from single-camera video recordings (Arastey, 2020). This technology enabled the tracking of body parts, resulting in a more accurate depiction of players movement velocity.

Research in this area has begun to explore the application of tracking technology in performance analysis in football, particularly talent identification. By training Convolutional Neural Networks, Theagarajan (2020) constructed an automated system that could; detect and track football players, classify the team of a detected player, and identify the player controlling the ball. The technology would then pool the extracted information to generate tactical statistics including the duration of ball possession, number of successful passes and number of successful steals for each player (Theagarajan, 2020). Although the automated system is unable to provide a comprehensive report of a player, it can alleviate the expensive and time-consuming process of scouting in football by providing a benchmark of key match statistics that allow recruiters to identify stand-out individuals. A combination of Theagarajan's tracking technology, and in-person scouting reports, can allow clubs to significantly improve the efficiency, and effectiveness of the scouting process.

Using Tracking Data to Visualise Tactical Analysis

Stein et al (2017) advanced the use of tracking data in football by developing deep learning technology that could more accurately track player movement via skeleton extraction and, as a result, visualise tactical elements of a game in real-time. The technology would not only track the players, but also their dependencies, influences and interactions with one another. To track these relationships between players, Stein et al (2017) developed the concept of "interaction spaces", which highlight areas that a player can reach before any opposing player, or the ball. The model would calculate the size and shape of a player's interaction space based on their speed, direction, and distance between opponents and the ball - as displayed in **Figure 1**. Stein et al (2017) also used the concept of interaction spaces to generate live telestrations overlaying game footage, such as arrows pointing to a player's passing options (shown in **Figure 2**), and displaying player cover shadows.

***Figure 1**: Interaction Spaces (Source: Arastey, 2020: Online)*

***Figure 2**: Visualising Passing Options (Source: Arastey, 2020: Online)*

Another way in which Stein et al (2017) contextualised automatic tracking data with region-based analysis, is the visualisation of a team's "free spaces" on the pitch. Stein et al (2017) developed the idea of free spaces by segmenting the pitch into individual grid cells, assigned to the player with the greatest probability of reaching the cell first. Similar to interaction spaces, Stein et al (2017) computed the probability of a player reaching a cell first based on

their speed, direction of movement, and distance to the cell. In theory, free spaces represent regions of the pitch controlled by the team in possession. Stein et al (2017) expands the concept of free spaces by allocating a value to the space based on its size, number of opposing players, and distance from the opposing goal. **Figure 3** displays a freeze-frame of the technology in use, with the high-value free spaces for the team in possession highlighted in blue.

***Figure 3**: High-Value Free Spaces (Source: Subsequent, 2023: Online)*

As part of the research, Stein et al (2017) gathered feedback on the technology from professional football coaches. Due to the analysis tools and visualisations being embedded in video recordings, the coaches appreciated the practical ability to conduct in-depth analysis directly from footage, and described the technology as “very advanced” in terms of application in practice (Stein et al, 2017). According to the coaches, the visualisation of free spaces help to effectively identify off-the-ball options for the team in possession (Stein et al, 2017). The coaches valued how the visualisations can be used to analyse and coach movement behaviours. Therefore, the analysis may also assist coaches in developing optimal training sessions, as the visualisations may indicate that the attacking movement from the forward players is good, but the progressive passes into these areas are lacking.

Tactical Analysis with Interactive Visualisation Systems

Seebacher et al (2021) advanced the practicality of tracking data and visualisation in the coaching process by developing an interactive system that can identify tactical behaviours in football. Working closely with coaches within a top-level football club in Europe, Seebacher et al (2021) designed a ‘magnetic tactic-board’ interface (**Figure 4**) to simplify the process of identifying, observing and communicating tactical behaviours and strategies of opposing teams.

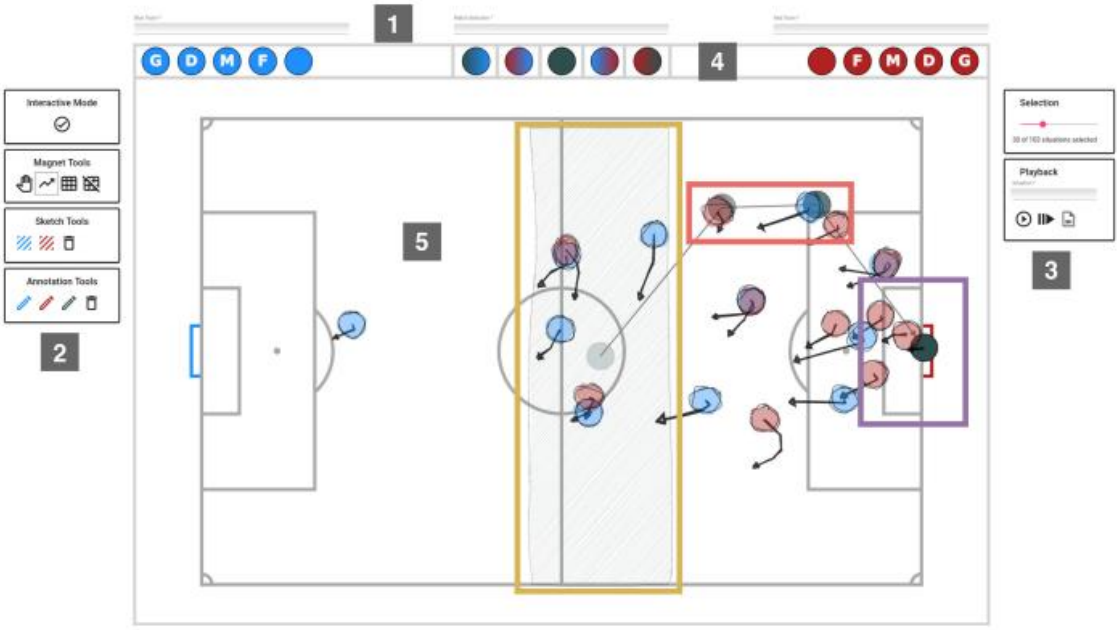

***Figure 4**: 'Magnetic tactic-board' Interface (Source: Seebacher et al, 2021)*

Using the interactive tool bar options, coaches and analysts can depict in-game scenarios by moving players and the ball (represented as magnets), to different areas of the pitch. The user can plot the trajectory of the ball or individual players, by dragging a magnet from its old position to a new position (Seebacher et al, 2021). Users can also assign the team in possession of the ball, or transitions in which the ball is turned over. Furthermore, users can request region-based situations by sketching a specific area of the pitch. Once a situation has been requested using the tool bar options, the system will search and aggregate all of the matches that the user has selected. The system will then visualise team formations and subsequent player movements (Seebacher et al, 2021). Additionally, the user can filter and select results for further analysis, as well as playback the animated or original video recording (Seebacher et al, 2021). **Figure 5** (Seebacher et al, 2021) demonstrates an image of the interface after a coach used the tool bar options to depict a situation where a team passed the ball through the midfield line of the opposing team.

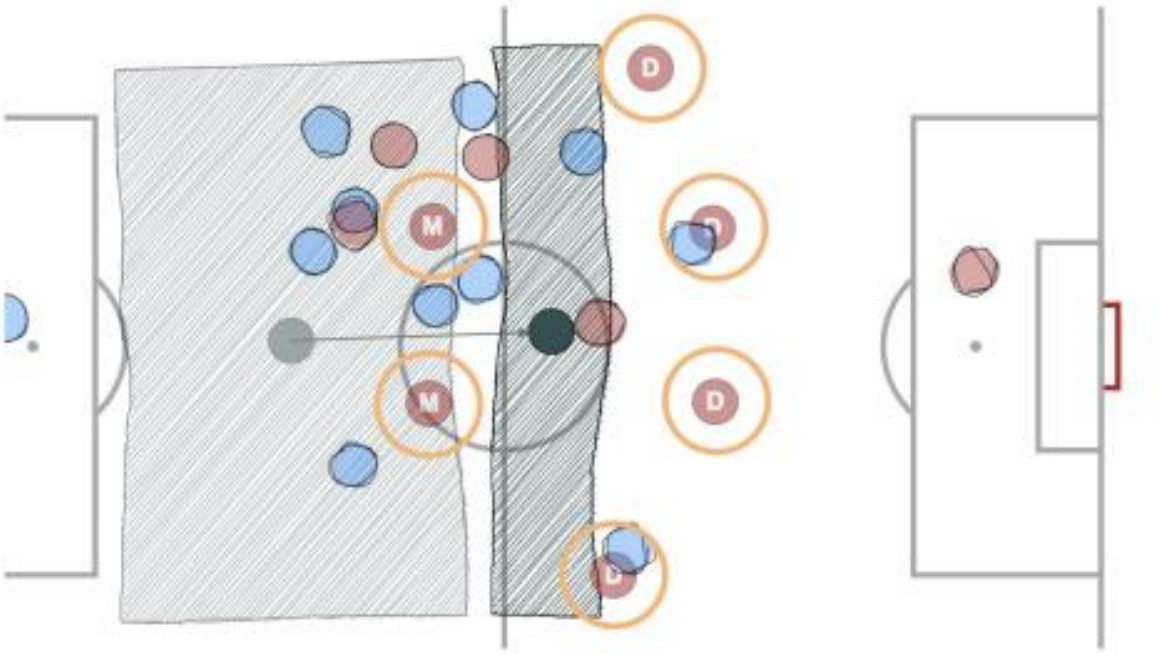

***Figure 5**: 'Magnetic tactic-board' Interactive Search Function (Source: Seebacher et al, 2021)*

Employing Seebacher et al's (2021) interactive visualisation system can greatly improve the efficiency and effectiveness of the performance analysis process in football. Seebacher et al (2021) ensured that the technology could deliver four key concepts to assist coaches in match preparation. Firstly, the technology can identify an opponent's strengths and weaknesses, allowing coaches to tailor training and strategies. Secondly, users can perform in-depth analyses of specific situations, such as set-pieces and formations across different phases of play. This improves the coaches' ability to anticipate and in turn counter a teams' play style. Thirdly, by providing coaches with direct access to match-specific situations, the technology supports efficient analysis by reducing the time and effort required for pre-match preparation. Increased efficiency is valuable for teams with limited preparation time due to busy schedules, or for low-budget teams who cannot afford a large-scale coaching and analysis department. Finally, by presenting the animations or match footage, the technology can be used to clearly communicate and demonstrate tactical insights to players. Feedback from several coaches in European first division football clubs support that the technology increases the accessibility of complex analytical processes and streamlines the exhaustive task of match preparation (Seebacher et al, 2021).

Multiple Object Tracking and the Coaching Process

The use of deep learning technology in multiple object tracking to automate the collection of statistical data and understand tactical behaviours has the potential to substantially improve productivity in the performance analysis process. The search function of Seebacher et al's (2021) interactive analysis system eliminates the need for analysts and coaches to analyse hours of game footage to decipher a team's playstyle. However, although tracking technology can enhance the coaching process, it is still important for coaches to interpret the data accurately to create an effective game plan. Furthermore, Seebacher et al (2021) acknowledges that the interactive system's search and filter function is still limited and adds that future work will look to implement situational parameters.

Other Applications of Multiple Object Tracking in Football

SkillsCorner employ multiple object tracking technology to provide specialised data analysis to football clubs including Crystal Palace F.C. and Racing Club F.C. (SkillsCorner, 2023). SkillsCorner work with scouts, analysts and coaching staff to interpret tracking data using context-specific metrics based on a team's game model. In addition to performance analysis, tracking technology can also be used in offside decision making. At the 2022 FIFA World Cup, multiple object tracking was employed to automate the offside decision making process. The technology combined deep learning with limb and ball tracking data to send alerts of offside incidents to the video operation room, where VAR officials validated the decisions (Pardo, 2022).

Conclusion

Performance Analysis Developments in Football

In this report, I have researched two developments in performance analysis in football and discussed their influence on an evidence-based coaching process. Furthermore, I have considered their potential future implications on the coaching process, as well as other areas of football where the technologies are or could be utilised.

For my first development, I investigated the application of neuroscience at FC Copenhagen and Liverpool F.C.. The F.C. Copenhagen academy employ neurofeedback training in the form of Virtual Reality exercises to analyse a player's cognitive profile, in addition to studying neuroscience concepts with coaches and players to improve the coaching process. Whereas, Liverpool F.C. use neurofeedback in one-on-one training with players to help them achieve an optimal mental state when taking set-pieces.

For my second development, I analysed the use of multiple object tracking technology in football through academic studies. Stein et al's (2017) research explored the use of tracking technology to create live visualisations embedded into game footage. Advancing his research further, Seebacher et al (2021) developed an interactive visualisation system that can be used by analysts and coaches to identify tactical behaviours in football.

In conclusion, both developments offer exciting opportunities for football clubs to implement or expand on performance analysis processes, that can improve the efficiency and effectiveness of the coaching process.

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