The influence of match phase and field position on collective team behaviour in Australian Rules football

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ABSTRACT

This study investigated the influence of match phase and field position on collective team behaviour in Australian Rules football (AF). Data from professional male athletes (years 24.4 ± 3.7; cm 185.9 ± 7.1; kg 85.4 ± 7.1), were collected via 10 Hz global positioning system (GPS) during a competitive AFL match. Five spatiotemporal metrics (*x*-axis centroid, *y*–axis centroid, length, width, and surface area), occupancy maps, and Shannon Entropy (ShannEn) were analysed by match phase (offensive, defensive, and contested) and field position (defensive 50, defensive midfield, forward midfield, and forward 50). A multivariate analysis of variance (MANOVA) revealed that field position had a greater influence on the *x*-axis centroid comparative to match phase. Conversely, match phase had a greater influence on length, width, and surface area comparative to field position. Occupancy maps revealed that players repositioned behind centre when the ball was in their defensive half and moved forward of centre when the ball was in their forward half. Shannon Entropy revealed that player movement was more variable during offence and defence (ShannEn = 0.82 – 0.93) compared to contest (ShannEn = 0.68 – 0.79). Spatiotemporal metrics, occupancy maps, and Shannon Entropy may assist in understanding the game style of AF teams.

Key Words: Performance analysis, Team tactics, Game style

INTRODUCTION

Collective team behaviour in invasion sports refers to how individual players position themselves across a field of play to form an overall group organisation (Rein and Memmert 2016). This behaviour has been used to describe team tactics or game style, whereby repetitive patterns of movement are formed (Sampaio and Macas 2012). Collective team behaviour has become a central component of match analysis (Clemente, Sequeiros et al. 2018) due to its established relationship with performance outcomes (Clemente, Couceiro et al. 2013, Goncalves, Marcelino et al. 2016, Rein and Memmert 2016) and the capability to provide greater context to match events (Lamas, Barrera et al. 2014).

Collective team behaviour has typically been defined via spatiotemporal metrics including *x*-axis centroid, *y*-axis centroid, length, width, and surface area (Frencken, Lemmink et al. 2011, Clemente, Couceiro et al. 2013, Folgado, Lemmink et al. 2014). The team centroid represents the geometric centre of all players on the field, which can be assessed in both the *x*-axis and *y*-axis, team length and width describes the distance between the two players furthest apart along the pitch and across the pitch respectively, and the team surface area signifies the region that encompasses all players across a field of play (Bartlett, Button et al. 2012). More recently, studies have visualised occupancy maps or heat maps and combined them with a measure of entropy to determine the variability of player movement (Couceiro, Clemente et al. 2014, Silva, Aguiar et al. 2014, Clemente, Sequeiros et al. 2018). To provide additional context to the understanding of collective behaviour, investigations have been separated into various phases of match play, such as offence and defence (Castellano, Álvarez et al. 2013, Clemente, Couceiro et al. 2013, Bialkowski, Lucey et al. 2014).

Research in football has considered the *x*-axis centroid and occupancy maps to suggest teams may be more attacking by positioning players higher up the field in both offence and defence during home matches compared to away matches (Lucey, Oliver et al. 2013, Bialkowski, Lucey et al. 2014). This behaviour may be associated with an increased possession in the forward third and a greater number of shots on goal (Lucey, Oliver et al. 2013, Bialkowski, Lucey et al. 2014). Irrespective of match location, a conservative approach is generally taken, with the team *x*-axis centroid located in their defensive half (Clemente, Couceiro et al. 2013). Investigations in football have used the length, width, and surface area to propose that whilst defending, teams will aim to compress the field of play by decreasing the area in which attacking players can operate (Vilar, Araújo et al. 2013). Increasing the number of defensive players surrounding an attacking team taking a shot at goal is associated with a concomitant decrease in successful scoring attempts (Ensum, Pollard et al. 2004, Wright, Atkins et al. 2011). Conversely, when teams are in offence they will attempt to spread the opposing defence to create more space (Castellano and Casamichana 2015). Defending players are then compelled to either restrict the impact of these players or hold their position to protect space closer towards their goal (Vilar, Araújo et al. 2013). Higher-ranking teams in football may therefore be more effective at accomplishing this as they commonly produce greater values of length, width, and playing space compared to their lower-ranked counterparts (Castellano, Álvarez et al. 2013).

Due to the continuous nature of invasion sports, it is difficult to associate discrete parts of collective team behaviour with a certain type of play (Lucey, Oliver et al. 2013). Specifically, it may be somewhat simplistic to assign specific movement behaviour to a particular tactic or game style, as a team’s movement behaviour is constantly influenced by emerging aspects of match play (Rein and Memmert 2016). Therefore, collective team behaviour may not necessarily be a preconceived team tactic or game style but rather an adaption to the general state of play (Rein and Memmert 2016). Thus, to gain a more comprehensive representation of team tactics or game style, researchers should account for contextual variables, such as match phase and field position (Castellano, Álvarez et al. 2013, Clemente, Couceiro et al. 2013, Alexander, Spencer et al. 2018). Research into collective team behaviour in Australian Football (AF) also remains largely absent, with only one study reported to date (Alexander, Spencer et al. 2018).

Australian Football is an invasion sport where teams compete on an oval shaped field (length = ~160 m, width = ~130 m). The match is separated into four quarters, contested by 22 players per team, with 18 on the field and 4 on an interchange bench (Gray and Jenkins 2010). Initial research in AF identified that teams display large variations in overall positioning throughout a match that may be influenced by the position of the ball (Alexander, Spencer et al. 2018). Therefore, field position of the ball may influence collective team behaviour (Alexander, Spencer et al. 2018). However, the extent to which collective team behaviour is influenced by match phase in relation to field position is yet to be investigated.

Determining collective team behaviour whilst accounting for contextual variables may provide a greater understanding of team tactics or game style. Therefore, this study investigated the influence of match phase and field position on collective team behaviour in AF.

METHODS

Data were collected from 22 male professional AF players (years 24.4 ± 3.7; cm 185.9 ± 7.1; kg 85.4 ± 7.1), recruited from a single team in the Australian Football League (AFL) competition. Participants took part in a match as part of the regular premiership season. All participants received information about the requirements of the study via verbal and written communication, and provided their written consent to participate. The University Ethics Committee approved the study.

The match took place on an oval shaped ground using dimensions 159.5 m x 128.8 m (length x width) with four 20-min quarters. Spatiotemporal data for all participants were collected using 10 Hz GPS devices (Catapult Optimeye S5, Catapult Innovations, Melbourne, Australia). The devices were housed in a sewn pocket in the jersey that is located on the upper back. The number of GPS satellites were greater than 8 packets per second, which ensured adequate signal quality (Corbett, Sweeting et al. 2017).

Spatiotemporal data was exported in raw 10 Hz format. Each file contained a global time stamp and calibrated location (*x*- and *y*- location). Match phase was determined via which team had possession of the ball (offensive, defensive or contest). The offensive phase was recorded when a team first gained possession of the ball and maintained it for at least a second and ended when the opposing team gained possession of the ball for at least a second or there was a stoppage in play. For example, the team scored or the ball went out of bounds (Yue, Broich et al. 2008). Using the same conditions, the defensive phase was recorded when the opposing team had possession of the ball (Yue, Broich et al. 2008). If neither team had possession of the ball, for example, when the officiating umpire returned the ball to play, the phase was considered to be in contest until a team gained possession of the ball for at least one second. All periods where the ball was out of play, for example, when there was a break between periods of play, celebration after goals, were excluded from the investigation. Field position of the ball was separated into four zones (defensive 50; D50, defensive mid; DMID, forward mid; FMID, forward 50; F50) by the two 50 m arcs and the centre of the ground (see Figure 1). The centre of the ground was signified as 0, 0. Match phase and field position were analysed via video observation and recorded to the nearest second by a commercial statistical provider (Champion Data Pty Ltd, Melbourne, Australia). Previous investigations have assessed the validity and reliability of similar match events (Robertson, Gupta et al. 2016). Positional data was then synchronised with match phase and field position data using the respective global timestamps. This was established using the initial point when the two widest players on the field converged from a stationary position prior to start of each quarter.

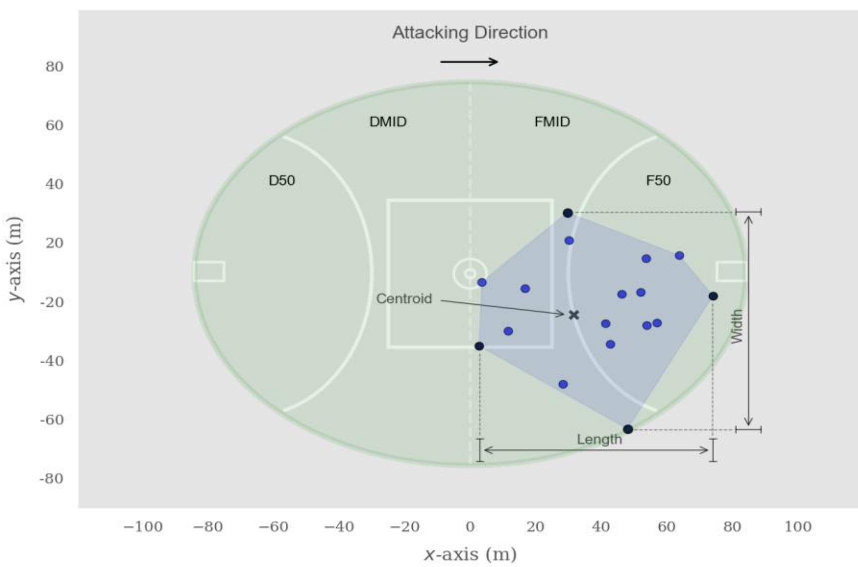

Figure 1: Four field position zones and spatiotemporal metrics including centroid, length, width, and surface area.

Five spatiotemporal metrics (Figure 1) were derived from the data to describe collective team behaviour. Team centroid was calculated as the mean (x, y) position of all players on the field (Frencken, Lemmink et al. 2011). Two measures were derived from the centroid position. These were the distance in the *x*-axis centroid (m) and the distance in the *y*-axis centroid (m) (Frencken, Lemmink et al. 2011). The team surface area was calculated as the total space (m) covered by a single team (Frencken, Lemmink et al. 2011). Team length was measured as the distance between the most forward and most backward player in the *x*-axis (m) and team width was defined as the distance between the two most lateral players on the ground in the *y*-axis (m) (Frencken, Lemmink et al. 2011). Variability of player movement was visualised via occupancy maps (Couceiro, Clemente et al. 2014, Silva, Aguiar et al. 2014), which represent the density of players across a given area (Silva, Aguiar et al. 2014). The occupancy maps were combined with Shannon Entropy (ShannEn) to provide an enhanced understanding of team movement variability. To calculate ShannEn, the field of play was quantised into bins of equal size ($1m^2$) to provide adequate spatial resolution (Couceiro, Clemente et al. 2014). The total count from each bin was used to determine the total time spent in each bin. A probability distribution of the total time spent in each bin was then used to determine the variability of a player being located in a specific bin. Both the heat maps and ShannEn values were normalised to total time spent in each position on the field for each match phase. Synchronisation and analysis were undertaken using the computational package Python version 3.2 with *Spyder*, which is part of the Anaconda software suite (www.python.org).

Statistical Analyses

Comparison of team *x*-axis centroid, *y*-axis centroid, length, width, and surface area were assessed between match phase (3 levels: Offence, Defence, Contest) and field position (4 levels: D50, DMID, FMID, F50), via a multivariate analysis of variance (MANOVA). Homogeneity was analysed using the Levene Test, which resulted in a lack of uniformity between match phase and field position. The *F* test was used to combat homogeneity violations due to the fact the total number of samples is in each group was essentially equal (Vincent 1999). Due to the non-homogeneity of the time series data, the Central Limit Theorem was considered, which allowed the assumption of normality to be made (Akritas 2004). Effect sizes were determined by calculating partial eta-squared (η_p^2) and was considered as small (η_p^2 < .06), moderate (η_p^2 > .06 η_p^2 < .15) or large (η_p^2 ≥ . 15) (Cohen 1988). Significant p values reported are < .001 unless otherwise stated. These calculations were determined using SPSS, v21.0; Inc., Armonk, NY, USA). Using Shannon Entropy *S*, the probability $p_{(i)}$ of finding a player in bin *i* was measured via quantising the field into *n* bins. Entropy was then normalised *N* to total match time spent in each position on the field for each phase of play to return a relative number between 0 and 1.

$$S\,(\%) = -\sum_{i=0}^{n-1} p\,(i)\log p\,(i) \log N$$

A low ShannEn (near 0) suggests the variability of player movement is low (Couceiro, Clemente et al. 2014). A high ShannEn (near 1) indicates the variability of player movement is high (Couceiro, Clemente et al. 2014). These calculations were completed using the computational package Python version 3.2 with *Spyder*, which is part of the Anaconda software suite (www.python.org).

RESULTS

Total differences between match phase and field position for each spatiotemporal metric are displayed in Figure 2. Individual playing sequences exhibited over time for field position and match phase are represented in Figure 3, while the distribution of these sequences are displayed in Figure 4. Heat maps and ShannEn values displaying player movement variability between match phase and field position are presented in Figure 5. The team observed in this study won the game 109 – 38.

Overall, field position had a greater influence on the *x*-axis centroid (η_p^2 = .41) when compared to match phase. Although, match phase had a greater influence on length (η_p^2 = .06), width (η_p^2 = .27), and surface area (η_p^2 = .14) when compared to field position. The *x*-axis centroid in the D50 was further behind centre when compared to the DMID (-10.7; 95% CI -11.2 – -10.2), FMID (-35.3; 95% CI -35.7 – -34.9) and the F50 (-48.1; 95% CI -48.6 – -47.7). The *x*-axis centroid in the DMID was also recorded further behind the FMID (-24.6; 95% CI -25.0 – -24.1) and F50 (-37.4; 95% CI -37.9 – -37.0), while the *x*-axis centroid in the FMID was recorded forward of centre it was still behind the F50 (-12.9; 95% CI -13.3 – -12.5). Length was greater during the DMID when compared to the D50 (22.9; 95% CI 22.3 – 23.6) and F50 (22.9; 95% CI 22.3 – 23.6). Length in the FMID was also greater than the D50 (8.1; 95% CI 7.6 – 8.7). Width was reduced in the D50 when compared to the DMID (-16.7; 95% CI -17.2 – -16.2), FMID (-10.6; 95% CI -11.0 – -10.2), and F50 (-14.5; 95% CI -14.9 – -14.0). The surface area in the DMID was larger when compared to the D50 (1900.3; 95% CI 1857.9 – 1942.8), FMID (976.4; 95% CI 934.4 – 1018.3), and F50 (1054.0; 95% CI 1012.3 – 1095.7). Surface area in the FMID was also larger when compared to the D50 (923.9; 95% CI 885.1 – 962.8) and F50 (77.6; 95% CI 39.6 – 115.7).

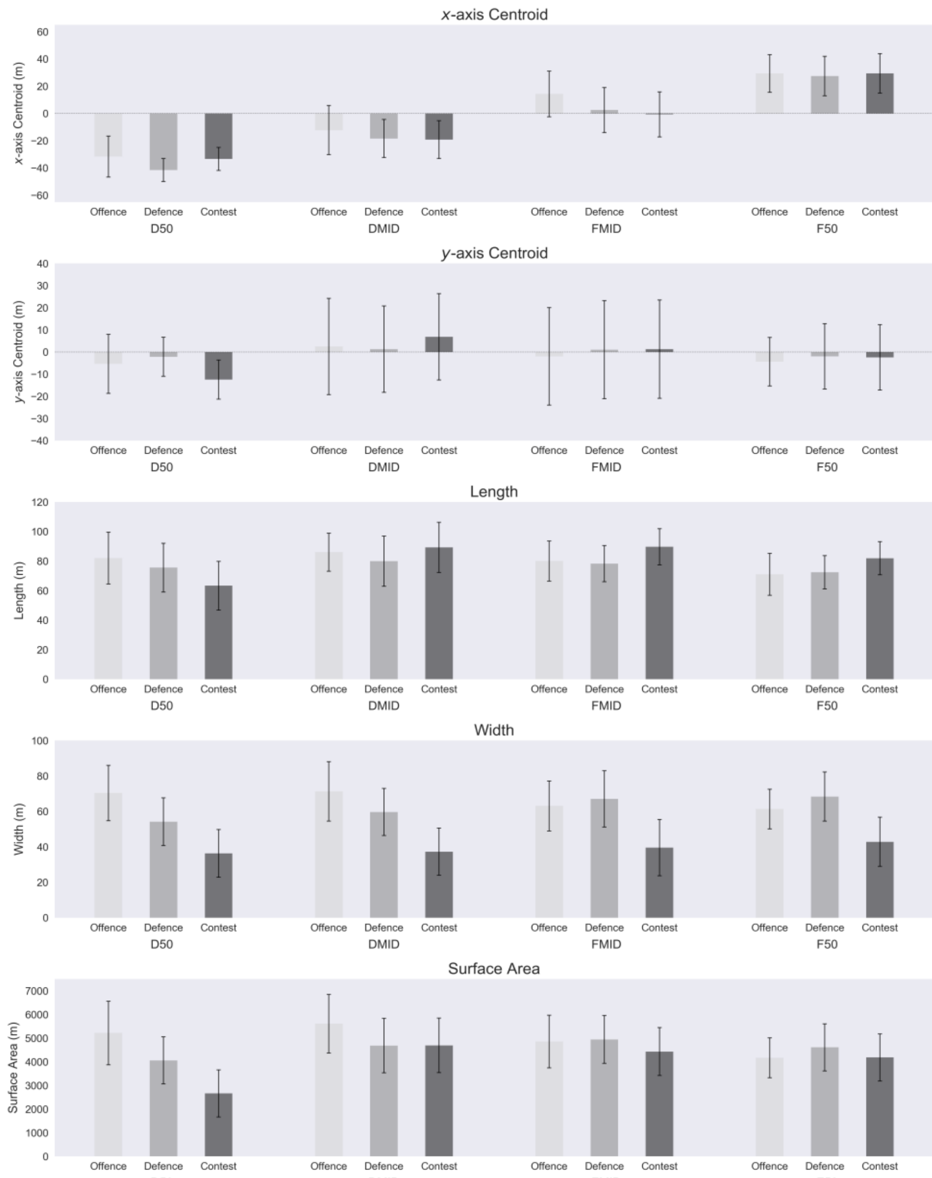

Figure 2: Comparison of mean ± standard deviation between match phase and field position of spatiotemporal metrics

Between-phase analysis recorded the *x*-axis centroid higher up the ground during offence when compared to defence (3.6; 95% CI 3.1 – 4.0) and contest (3.3; 95% CI 2.6 – 4.0). Length was greater during offence compared to defence (4.7; 95% CI 4.2 – 5.3), while contest was greater than offence (3.5; 95% CI 2.5 – 4.5) and defence (8.2; 95% CI 7.2 – 9.3). Width was greater during offence when compared to defence (3.3; 95% CI 2.9 – 3.8) and contest (27.9; 95% CI 27.2 – 28.7). Width was also greater during defence compared to contest (24.6; 95% CI 23.8 – 25.4). Surface area was greater during offence compared defence (397.5; 95% CI 359.8 – 435.2) and contest (794.2; 95% CI 727.4 – 861.0). Surface area during defence was also greater than contest (396.8; 95% CI 327.8 – 465.8).

Visual inspection of the distribution plots (Figure 4) displayed similar time duration for offensive and defensive sequences with the majority of playing sequences between 0 – 20 seconds. Total time during contest was reduced with the majority of sequences measuring between 0 – 10 seconds.

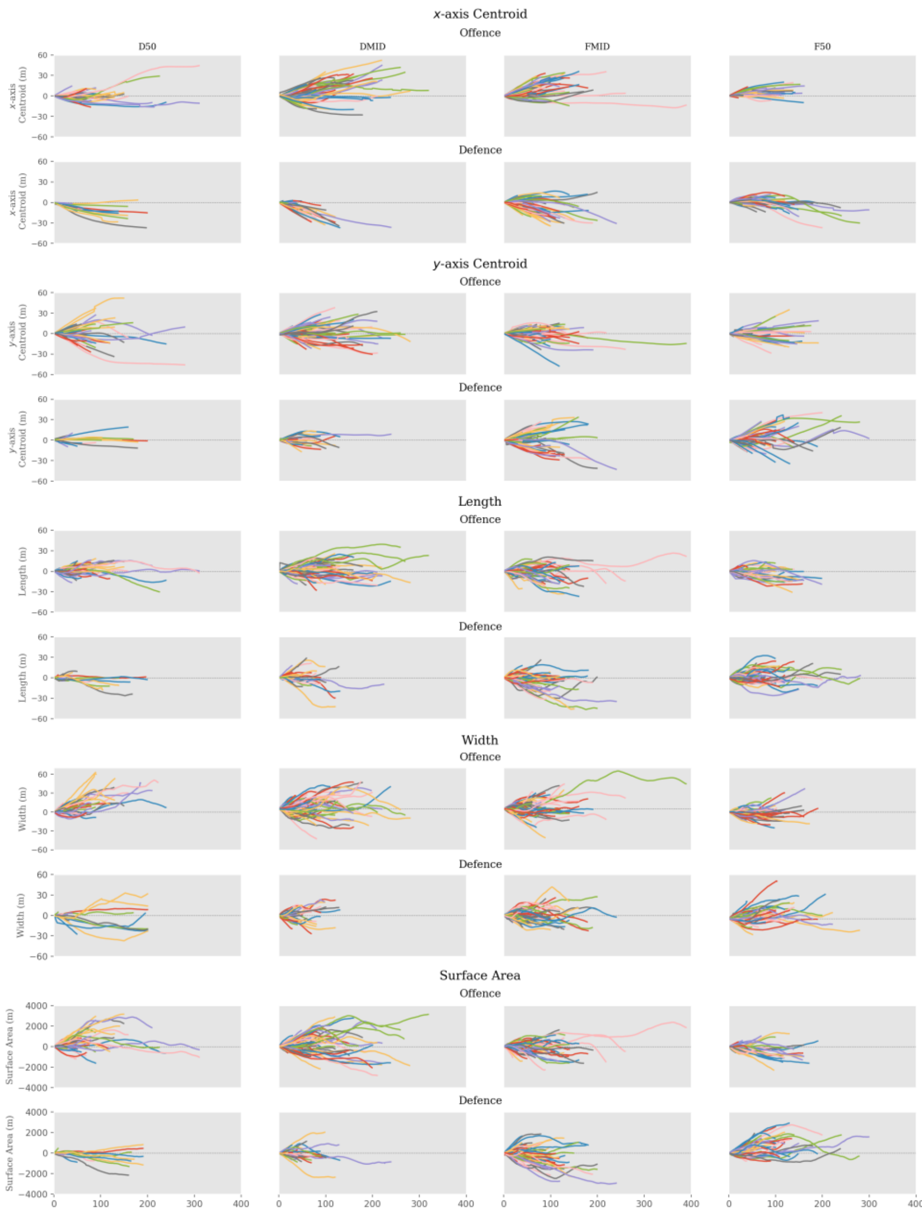

Figure 3: Comparison of individual instances of spatiotemporal metrics in relation to the duration of time for match phase and field position

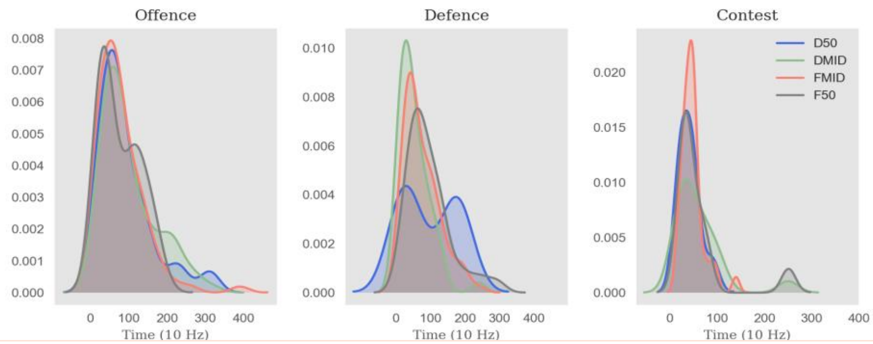

Figure 4: Between match phase comparison of the distribution of total time for field position

ShannEn values (Figure 5) were greater during offence and defence compared to contest. Between field position analysis indicated that variability of team movement decreased during defence when in the D50 and in offence when in the F50. ShannEn values were greater during contest when the ball was in the middle of the ground compared to D50 and F50.

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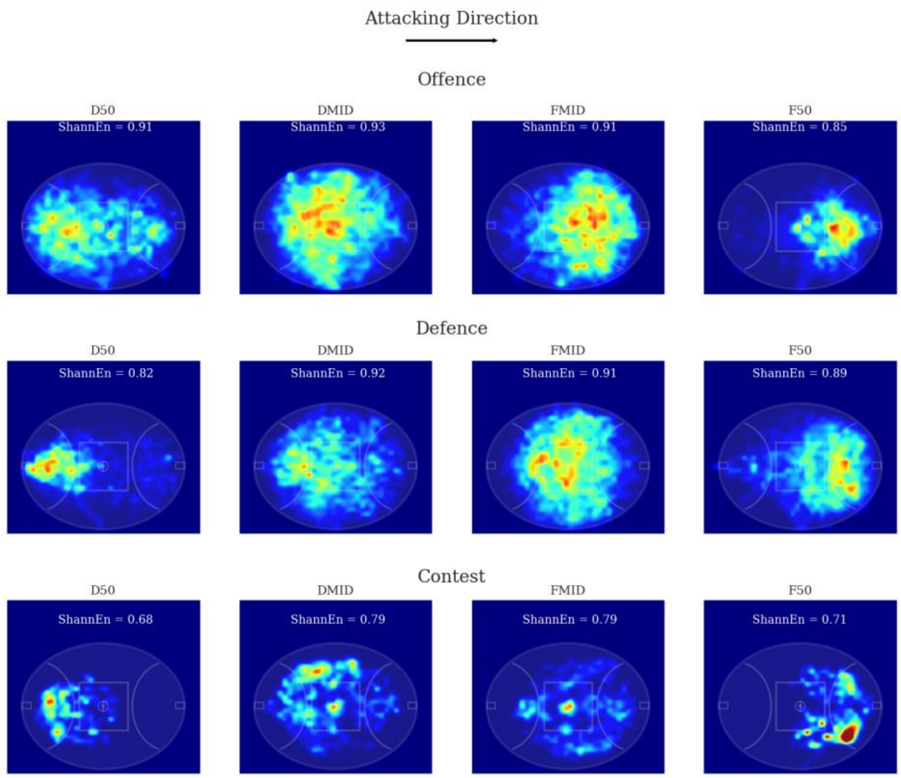

Figure 5: Comparison of occupancy maps and ShannEn values for match phase and field position

DISCUSSION

This is the first study to investigate the influence of match phase and field position on collective team behaviour in AF. This proof of concept study may be used to provide a complementary framework to add to existing match analyses common in AF. Specifically, the addition of spatiotemporally-derived metrics relating to collective team behaviour has the potential to provide both enhanced insights and context to existing consideration of discrete team and player performance indicators.

A predominant finding was field position had a greater influence on the *x*-axis centroid when compared to phase of play. Conversely, phase of play had a greater influence on length, width, and surface area when compared with field position. Players collectively transitioned closer to their goal when the ball was in their defensive half and pressed higher up the field when the ball was in their forward half. Variation in player movement, as signified by ShannEn, increased through FMID and DMID compared to F50 and D50 and during offence and defence when compared to contest.

Overall, the majority of players were positioned close to where the ball was situated. The density of players was more pronounced when the ball was in the D50 or F50 and further amplified when in the contested phase. Length, width, and surface area were also reduced under these circumstances. This type of behaviour may be associated with players trying to reduce the amount of space an opposition can operate in (Vilar, Araújo et al. 2013) and is also representative of AFL rules, whereby no movement restrictions are imparted on players. This behaviour could be beneficial when defending in the D50 as it may be more difficult for the opposing team to achieve an effective shot on goal if an increased number of players are located within this area (Ensum, Pollard et al. 2004, Wright, Atkins et al. 2011). Alternatively, when the ball is located in the F50 it may be more difficult for the opposing team to successfully move the ball out of this area if players have setup an effective ‘barrier’ behind the ball. Increased width and variation in player movement throughout the middle of the ground comparative to the F50 and D50 areas may also be somewhat attributed to the oval shaped field dimensions of an AF ground. However, reduced entropy in these areas during the contested phase suggests movement variability may differ between field position and match phase. Increased variability during offence in the D50, DMID, and FMID could indicate players may be utilising various movement patterns to disrupt opposing defensive structures (Garganta 2009). Reduced movement variation during the contested phase may reflect the inactive period, prior to a change in match phase. The duration of playing sequences during the contested phase was also reduced when compared to offensive and defensive phases. In the present study, while players may produce less movement variation during contest, they are required to be prepared to react when either team gains possession of the ball.

Studies investigating the physical movement output of team sport athletes through the duration of time are ubiquitous (Brewer, Dawson et al. 2010, Wisbey, Montgomery et al. 2010, Dwyer and Gabbett 2012). However, there is limited research on the duration of time with respect to collective team behaviour. Findings from the present study indicate the time duration of playing sequences before a change in field position are generally between 0 and 20 seconds for offensive and defensive phases and 0 to 10 seconds for the contested phase. The combination of spatiotemporal metrics, heat maps, and entropy measures may assist in measuring particular collective team behaviour, which can be used to design more representative training regimes. For instance, if the ball is in the forward half, players may be instructed to press higher up the field in a certain period of time to generate enough pressure to keep the opposition from moving outside this zone. Alternatively, an aim to maintain possession of the ball may be more attainable if surface area is being created when initially gaining possession of the ball. Opposition analysis may also be benefit from a greater understanding of rival collective team behaviour. For example, an opposing team that quickly transitions players deep in their defensive end after losing possession of the ball defence could cause increased space through the middle of the ground. This could be exploited by employing a higher possession style of play with a slower build-up that reduces the risk of losing possession.

Collective team behaviour investigations in football have revealed that a more defensive game style is generally employed by preserving players behind the centre of the field (Clemente, Couceiro et al. 2013). However, teams may be inclined to engage in a more offensive game style during home matches compared to away matches by positioning players higher up the field (Lucey, Oliver et al. 2013, Bialkowski, Lucey et al. 2014). Higher ranked football teams may also display a more expansive game style with greater values of length, width, and surface area during the offensive phase of play (Castellano, Álvarez et al. 2013, Castellano and Casamichana 2015). Results from the present study suggest AF teams may undertake a more circumstantial approach in allocating players to achieve certain tasks. Teams may aim to restrict space if the ball is in their D50 and press higher up the field to hold the play in their forward half when the ball is in their F50. Increased variation in player movement also exists during the middle of the ground. However, it is difficult to discern if these types of behaviour are a predetermined game style or if its players adapting to the emergent state of the game. For instance, length, width, and surface area appear to be influenced by match phase, while the *x*-axis centroid is influenced by field position. As such, an increased time spent in offence may be the cause of a team's increased surface area and not necessarily a premeditated approach to commit to a more expansive game style. In addition, a team's inability to move the ball out of its defensive half may represent why the *x*-axis centroid is behind centre, instead of a defensive strategy to preserve players closer to their own goal.

Whilst contextual factors provide a more informed understanding of how collective behaviour changes during different game states, it is misleading to solely associate collective behaviour with specific team tactics or game style. The current macroscopic approach determines player positioning during a specific match phase or field position to infer game style or team tactics. A more granular approach is required that better reflects the different strategies a team might employ during different situations. Specifically, a microscopic method that determines group structures or formations at each point of time will provide a more representative comprehension of game style. This information should be combined with match events or performance outcomes to better understand the efficacy of various playing styles.

Some limitations relating to sample size and amount of teams included in this study should be recognised. The present study analysed the collective team behaviour of one club during a single competitive match. Thus additional research should include multiple clubs throughout several matches to construct a more accurate representation of collective behaviour of AF teams and if any variances between teams exist. Future investigations may also analyse the player movement during various contextual variables to gain a more comprehensive understanding of AF collective team behaviour. Relationships between the observed collective team behaviour from this team and specific strategy or team tactics are not yet known. Future work may also incorporate a more granular approach that includes how collective team behaviour form specific structures in real time. In addition, this analysis should incorporate match events (Corbett, Bartlett et al. 2018) or performance outcomes to provide a more representative understanding of team tactics or game style.

CONCLUSION

This study investigated the influence of match phase and field position on collective team behaviour in AF, thereby providing a proof of concept for future work in this area. When considering field position and match phase, the variation in the *x*-axis centroid could be attributed to the change in field position, while match phase had a greater influence on length, width, and surface area. Players were more inclined to re-position closer to their defensive end to restrict space when the ball was closer to their goal and conversely, press higher up the field when the ball was in their forward half. Future investigations of collective team behaviour in AF should look to measure specific formations and structures continuously. This information, with the combination of match events, may provide a more representative understanding of game style or team tactics.

DECLARATION OF INTEREST

The authors report no conflicts of interest.

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