

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/371124501>

ORIGINAL SCIENTIFIC RESEARCH STUDY | COLLECTIVE BEHAVIOURS INFLUENCING PHASE OF PLAY SUCCESS IN AUSTRALIAN FOOTBALL

Article · January 2023

CITATIONS

0

READS

70

5 authors, including:



William Sheehan

University of Technology Sydney

20 PUBLICATIONS 170 CITATIONS

SEE PROFILE



Rhys Tribolet

University of Technology Sydney

21 PUBLICATIONS 249 CITATIONS

SEE PROFILE



Andrew Novak

University of Technology Sydney

63 PUBLICATIONS 873 CITATIONS

SEE PROFILE

Job Fransen

Charles Sturt University

131 PUBLICATIONS 3,380 CITATIONS

SEE PROFILE

Original Scientific Research Study

COLLECTIVE BEHAVIOURS INFLUENCING PHASE OF PLAY SUCCESS IN AUSTRALIAN FOOTBALL.

William B. Sheehan¹, Rhys Tribolet¹, Andrew R. Novak^{1,2}, Job Fransena¹, Mark L. Watsford¹¹Human Performance Research Centre, School of Sport, Exercise and Rehabilitation,
Faculty of Health, University of Technology Sydney, Sydney, New South Wales, Australia.² High Performance Department, Rugby Australia, Sydney, New South Wales, Australia.

BLUF

The different physical and spatiotemporal characteristics associated with successful phases of play in professional Australian Football provide novel coaching implications for conditioning, practice, and game plan design.

ABSTRACT

Despite advancements in the scale of data available for quantifying the physical and spatiotemporal characteristics of match play, few studies combine these aspects in professional sport. This study related these components to behaviours associated with successful outcomes across various phases of play. A retrospective cross-sectional design was utilised with team physical and spatiotemporal variables obtained from professional Australian Football League games via global navigation satellite system devices. A binomial generalised mixed effects regression model was used to estimate the effects of phase duration, physical and spatiotemporal variables on the probability of a successful outcome in different phases of play (contested play, defence, offence, set shot, goal reset, umpire stoppage). From a physical perspective, the addition of fixed effects, namely duration, low-moderate volume, high speed running, explosiveness, change of direction, and impacts, to a model that contained only the random intercept were significantly improved between model and data for offensive, defensive, and contested phases of play. Further, the addition of spatiotemporal fixed effects including dispersive coordination, lateral unpredictability and spacing, multidirectional synchrony, longitudinal unpredictability, and longitudinal behaviour, also significantly improved the model for the same phases of play. This was the first study to concurrently examine differences in physical and spatiotemporal characteristics with respect to successful outcomes in different phases of play. These novel insights may provide coaching direction for conditioning, practice, and game plan design. For example, implementing reactive agility drills during conditioning bouts may assist in developing change of direction ability which may be important for offensive success. Alternatively, setting up training drills that provide less relative space per player in offence may force players to utilise change of direction ability over high speed running.

Key Words - Performance analysis; Tactical analysis; Team Sport; GPS; GNSS.

INTRODUCTION

Australian football is an 18 versus 18 (with 4 substitutions on each team) contact sport played on an oval shaped field. From an ecological dynamics perspective, Australian Football is a complex performer-environment subsystem where players and teams use information embedded within their performance environment to guide their actions and decision making. Information-rich environments consisting of teammates, opposition players, line markings, umpires, etc., afford opportunities for players to self-organise and coordinate behaviour in a way that allows the team to achieve the main objective of the game, to score the most points through goal-kicking. (9) To adequately achieve task goals while satisfying constraints, players require skilled behaviour, physical abilities and tactical strategies to co-adapt to the dynamic nature of match play as well as cope with the ever-changing demands of the game from season to season. (30) As a result, a thorough understanding of the complex interactions between the individual within their performance environment and the task at hand is required to capture the complexity of Australian football performance.

Performance analysis in professional Australian Football has progressively evolved over the last 40 years and has proven to be integral for understanding the different constituents of match play allowing practitioners to adequately capture the complexity of Australian Football by quantifying these components. (10) Analysis of these constituents has included the assessment of discrete, technical, on-field actions such as frequency of kicks, handballs, possessions and marks, (17) which have been able to contribute to models predicting performance outcomes. (13, 24, 29, 30) Additionally the physical characteristics of the game have been extensively quantified using microtechnology such as global navigation satellite system (GNSS) devices and accelerometers. (30) More recently, with recent technological advancements, including the increase in sensitivity and application of GNSS devices and the accessibility of novel statistical approaches, it is possible to objectively measure and quantify collective team movement (spatiotemporal characteristics) providing insight into tactical strategies and behaviours. Spatiotemporal analysis using these metrics

can be undertaken to identify synergistic and co-adaptive behaviours that emerge on an intra-team level, i.e. between players of the same team. (3)

The technical, physical and tactical areas of analysis have provided guidance and direction for coaches and practitioners when it comes to the analysis of match performance and development of representative training tasks. In the past decade, applied research in Australian Football has investigated these factors, each with a wide array of variables, to derive practical applications aimed at improving a team's performance. Currently in the Australian Football League (AFL), the pinnacle of Australian Football, all professional teams evaluate the physical characteristics of game play using GNSS technology which are capable of providing a wide array of associated variables e.g. total distance, average speed, high-speed running, and acceleration characteristics. (30) As a result, the external physical characteristics of the game have been documented extensively. (5, 13, 15, 19, 30) Across the course of a match, players accumulate higher running volumes than any other team invasion sport whilst completing frequent intermittent bouts of high-speed running, accelerations, decelerations, changes of direction and frequent collisions with opposing players. (10, 34) While microtechnology data have provided valuable information regarding the physical characteristics of match play, inconsistencies and discrepancies exist between indicators of successful and unsuccessful performance. (13, 29) For example, when examining differences in quarters won and lost, one study associated lower physical output for quarters that were won, (29) while conversely another failed to identify any relationship between physically derived metrics and quarter outcome. (13) Discrepancies may arise as these studies may have failed to fully account for the physical characteristics of match play through the selection of only a few GNSS derived variables. Further, examining behaviour across the entirety of a match, or a quarter, may fail to fully account for the complexity of the sport or be specific enough to delineate the influence of physical components on match success. (11)

In an attempt to capture the complexity of Australian Football, Gronow and colleagues compared the amount of time spent in four different speed zones when the reference team was in offence or defence over the length of a quarter. (11) The results may explain previous discrepancies with contrasting behaviour demonstrated in offence and defence. For example, in quarters won, more time was spent below 14km/hr in offence and less time at speeds greater than 14km/hr while in defence more time was spent at speeds greater than 14km/hr and less time below 14km/hr. The authors suggested that the ability to control the pace of the game through the control of possession, and subsequent creation of more disposal options, may have attributed to the lower physical characteristics of offensive plays. (11)

Results from this line of enquiry highlight the importance of examining specific phases of play as this may provide greater insight than analysing behaviour over the course of a quarter or match. Theoretically, across the course of a game an equivalent amount of time spent attacking and defending may reveal minimal differences in physical output when comparing wins and losses as both these phases appear to elicit conflicting physical demands. While this study provided further insight for practitioners into the physical characteristics associated with offensive and defensive phases of play and the association with quarter success, this study was limited to the use of four physical variables, pertaining to linear velocities, which may fail to encapsulate all the physical characteristics associated with Australian Football. (10, 34) Additionally, contested plays and stoppages were both neglected from physical analysis despite being considered important components of Australian Football match play. Inclusion of these phases may further clarify the influence of physical output during specific match periods on quarter or game outcomes. (20)

The aforementioned limitations were addressed to some extent by Rennie and colleagues who assessed four additional physical variables (total distance, relative distance, accelerations and decelerations) during all phases including stoppages and contested phases of play. (20) As expected, there were differences across all phases of play with stoppages demonstrating markedly lower physical output in all areas providing implications for the inclusion of match specific recovery cycles in training designs. (20) While offensive and defensive phases were relatively similar across all variables, players accumulated more high speed running volume over all other phases. The inclusion of accelerometry data also offered novel insight into the physical characteristics of contested phases with this passage of play accumulating more total distance, number of accelerations and number of decelerations than all other phases potentially reflecting the change of direction demands and unpredictable nature of game play during contested phases of play. (20) However, as player geospatial positioning was not objectively assessed in the analysis, reasons for the greater observed accelerometry metrics can only be theorised. Only recently have the validity of these claims been supported with contested phases demonstrating lower values of synchrony and coordination. (25) Additionally, while the description of physical characteristics associated with each phase of play provided novel insight, the study was delimited to eight physical variables using a reductionist approach, potentially neglecting other important physical characteristics associated with Australian Football match play. (10, 34) Further, these characteristics were not concurrently assessed with respect to performance success such as quarter or match success.

To-date, only one paper has examined the spatiotemporal differences between phases of match play with respect to wins and losses in Australian Football. Incorporating spatiotemporal metrics, greater values in length, width, and surface area were observed during offensive phases comparative to defensive and contested phases. (2) This increase in dispersion may be indicative of players trying to spread the opposition defending players to create a greater effective playing space, which allows for an easier passage of the ball towards the goals to provide scoring opportunities. Alternatively, the lower values of dispersion may be indicative of a collective team movement to close down space and

prevent the opposition team from maintaining or transferring possession. (2) While these measures provide some insights into potential tactical mechanisms that influence team success, only a limited number of spatiotemporal metrics were utilised limiting the analysis of tactical behaviour. Incorporating variables that can measure the dynamic properties of spatiotemporal metrics, such as how they change and persist over time are crucial in describing the dynamic nature of match play. Therefore, the inclusion of variables such as variability, (28) synchrony (23) or predictability, (8) obtained from time series of spatiotemporal measures, may offer new insights into the tactical behaviour of Australian Football teams during competitive match play. Further, despite the important tactical elements associated with stoppage phases, these phases were neglected from the analysis. Information pertaining to this phase may still be of interest as often players need to quickly organise offensive and defensive structures and jostle for superior position to win the ball. (20) Finally, the study sample incorporated two 20-minute halves in a 15 versus 15 match simulation drill, and therefore the representativeness of the collective behaviour exhibited by teams during competitive match play is questionable. While this provides a foundational understanding, further research investigating these metrics in AFL matches with a broader array of spatiotemporal measures, including variables capturing the dynamics of tactical behaviour may enhance the understanding of the influence of spatiotemporal tactical behaviour on performance outcomes. This may subsequently provide useful applications for representative training design that incorporates physical and tactical behaviours reflective of match-play.

While technological advancements in GNSS technology and the accessibility of statistical techniques that can more readily capture the complexities of performance have drastically increased the amount of available information to quantify match characteristics, this has concurrently convoluted existing findings and made variable selection for performance analysis an arduous task. With many physical and spatiotemporal metrics available for practitioners, as demonstrated, study designs have only incorporated a select number of variables which may fail to encapsulate the full complexity of the game and lead to existing discrepancies in the literature. A viable option for overcoming this issue is to dimensionally reduce the large number of available variables using statistical procedures such as a principal component analysis in conjunction with domain expertise. These dimension reduction methods have no real pedigree in performance analysis science, but principal component analysis and exploratory or confirmatory factor analysis have been used extensively in other research areas such as the development and analysis of psychological questionnaires. (16) Recent lines of enquiry have successfully reduced a large number of physical variables (26) and spatiotemporal variables (27) whilst maintaining a large proportion of variance from the original dataset, facilitating their practical use and interpretability. This approach allows analysts to practically examine the different constituents of match play whilst minimising the risk of omitting important information. However, these metrics are yet to be examined in Australian Football with respect to performance outcomes.

Accordingly, this study used the physical (low-moderate volume, high speed, explosiveness, change of direction and collisions/impacts) (26) and spatiotemporal (dispersive coordination, lateral unpredictability and spacing, multidirectional synchrony, longitudinal unpredictability and longitudinal behaviour) (27) metrics derived by Sheehan and colleagues to examine behaviours associated with successful phase outcomes across the various phases of play (Table 1). It was hypothesised that successful offensive phases would reveal lower values than unsuccessful phases in all physical metrics as well as decreased multidirectional synchrony and increased lateral unpredictability and spacing, longitudinal unpredictability and longitudinal behaviour. Comparatively, successful defensive phases would exhibit higher physical demands than unsuccessful phases along with superior scores of multidirectional synchrony coupled with lower scores in all other spatiotemporal variables. Further, in contested phases, due to their unpredictable nature, it was expected that higher low-moderate game volume, change of direction and collisions/impact scores along with greater lateral unpredictability and spacing, longitudinal unpredictability and lower multidirectional synchrony would align with successful outcomes. Due to their relatively lower physical demands and predictable nature, set shots, goal resets and umpire stoppages were hypothesised to present lower lateral unpredictability and spacing, longitudinal unpredictability and superior multidirectional synchrony in phases with a successful outcome due to an enhanced ability to coordinate movements and self-organise.

Table 1 - Operational definition for each phase of play coded during analysis with definitions of successful outcomes for each phase of play as determined by coaching staff.

Phase	Definition
Offence	The reference team has clear control of the ball via a hard ball get, a mark, handball, or an intercept during open play. A turnover from penalty, infringement or behind also constitutes a change in possession. Successful phases lead to an entry inside the attacking 50 arc (inside 50) or a scoring opportunity (set shot or a goal or behind scored in general play).
Defence	The opposition team has clear control of the ball via a hard ball get, a mark, handball, or an intercept during open play. A turnover from penalty, infringement or behind also constitutes a change in possession. Successful phases lead to a direct turnover (interception) or a contested play/umpire stoppage further away from its origin in the attacking direction, i.e., further away from the defending goal.
Contested Play	Neither team has clear control or possession of the ball due to tackling or opposition pressure. The ball is not secured via a mark or clean receive from a teammate. Successful phases lead to possession of the ball, i.e. precedes an offensive phase.
Goal Reset	Includes the duration between the umpire signalling a goal has been scored to the proceeding centre bounce. Successful phases precede a contested play with a successful outcome.
Umpire Stoppage	The umpire signals a stoppage in play to indicate a ball up, boundary throw-in. Blood rules or stoppages due to injury were excluded from the analysis. Successful phases precede a contested play with a successful outcome.
Set Shot	Commences the moment a player marks the ball in a scoring position, executes the shot and the umpire indicates either a goal or behind. If an umpire requests a score review, the phase is defined as an umpire stoppage. Successful phases that occur in a quarter that is won.

METHODS

Approach to the Problem

The study followed a retrospective cross-sectional design where one team's physical and spatiotemporal behaviours, as measured via GNSS technology during official AFL games was collected from a period spanning one season.

Subjects

The study sample consisted of 35 male professional Australian Football players (age: 25.2 ± 3.9 years; playing experience: 5.7 ± 3.7 years) from one AFL team. 17 senior matches from one season (2018) provided 9788 observations (phases of play) from one designated AFL team. The procedures used in this study were conducted with ethics approval from the Human Research Ethics Committee of the local institution.

Procedures

Data pertaining to the players' latitudinal and longitudinal positioning were collected via the use of GNSS units sampling at 10Hz ('Optimeye S5', Catapult Sports, Melbourne, Australia). Following each match, video footage was manually coded for phases of offence, defence, contested play, umpire stoppage, set shot, and goal reset using SportsCode (SportsTec Limited, Warriewood, Australia). The operational definitions for these phases of play are described in Table 1 in accordance with previous research. (20, 21) Successful phase outcomes were also manually coded and are also defined in Table 1. These definitions were derived, and agreed upon, from discussions with the coaching group at the football club. Spatiotemporal variables were calculated from raw individual player latitudinal and longitudinal positional data via MATLAB software using methods previously outlined by Sheehan et al..(27, 32) Physical and spatiotemporal sum scores were then generated from the raw data for each phase of play using factor loadings previously derived via principal component analyses (Table 2). (26, 27) Sum scores were then converted to z-scores and normalised to the same unit and magnitude, with a mean of 100 and a standard deviation of 15 (quotient score = $100 + (z\text{-score} * 15)$) to facilitate interpretation of variables measured on different scales. (12)

Table 2 - Physical and spatiotemporal equations derived by Sheehan and colleagues.

Component	Calculation	Description
Physical		
Low-Moderate Volume	$0.869 \times \text{Velocity Band 3 Distance} + 0.835 \times \text{Total Distance} + 0.807 \times \text{Deceleration Band 1 Efforts} + 0.805 \times \text{Acceleration Band 1 Efforts} + 0.772 \times \text{Velocity Band 3 Efforts} + 0.727 \times \text{Velocity Band 4 Efforts} + 0.713 \times \text{Velocity Band 2 Distance} + 0.652 \times \text{Velocity Band 4 Distance} + 0.649 \times \text{Acceleration Band 1 Distance} + 0.621 \times \text{Deceleration Band 2 Efforts} + 0.605 \times \text{Deceleration Band 1 Distance} + 0.560 \times \text{Acceleration Band 2 Efforts}$	Superior scores indicate the accumulation of physical match load at low-moderate intensities.
High Speed Running	$0.833 \times \text{Velocity Band 6 Distance} + 0.830 \times \text{Velocity Band 6 Efforts} + 0.823 \times \text{Velocity Band 5 Distance} + 0.701 \times \text{Velocity Band 5 Efforts}$	Superior scores indicate that greater volume of high speed metrics have been accumulated.
Explosiveness	$0.878 \times \text{Acceleration Band 3 Efforts} + 0.858 \times \text{Acceleration Band 3 Distance} + 0.823 \times \text{Acceleration Band 2 Distance}$	Superior scores reflect acceleration capability and an ability to rapidly change velocity.
Change of Direction	$0.899 \times \text{IMA Acceleration High} + 0.885 \times \text{IMA Change of Direction Right High} + 0.862 \times \text{IMA Change of Direction Left High} + 0.738 \times \text{IMA Acceleration Medium} + 0.712 \times \text{IMA Change of Direction Right Medium} + 0.706 \times \text{IMA Change of Direction Left Medium} + 0.526 \times \text{IMA Acceleration Low} + 0.455 \times \text{IMA Change of Direction Right Low} + 0.415 \times \text{IMA Change of Direction Left Low}$	Superior scores reflect high intensity and frequent changes in direction.
Collisions/Impacts	$0.740 \times \text{IMA Deceleration Medium} + 0.654 \times \text{IMA Deceleration Low} + 0.617 \times \text{IMA Jump Low} + 0.607 \times \text{IMA Deceleration High}$	Superior scores may indicate a higher number of collisions or impacts accumulated.
Spatiotemporal		
Dispersive Coordination	$-0.923 \times \text{Stretch Index SaEn} - 0.823 \times \text{Surface Area SaEn} + 0.891 \times \text{Stretch Index CV} + 0.684 \times \text{Surface Area CV} + 0.850 \times \text{Team Stretch Index Correlation}$	Superior scores may indicate that players are dispersing in a varied but unison manner.
Lateral Unpredictability and Spacing	$-0.933 \times \text{Centroid Lateral Correlation} + 0.694 \times \text{Centroid Lateral SaEn} + 0.923 \times \text{Surface Area} + 0.832 \times \text{Stretch Index} + 0.536 \times \text{Team Stretch Index Rho}$	Superior scores may indicate that the team is moving in an unpredictable manner in the side-to-side direction with a shape that is largely dispersed.
Multidirectional Synchrony	$0.955 \times \text{Centroid Longitudinal Rho} + 0.936 \times \text{Centroid Lateral Rho}$	Superior scores may indicate that the change in player displacement in the end-to-end and side-to-side direction relative to the team is in-phase.
Longitudinal Unpredictability	$-0.815 \times \text{Centroid Longitudinal Correlation} + 0.694 \times \text{Centroid Longitudinal SaEn}$	Superior scores may be indicative of unpredictable behaviour and a lack of coordination in the end-to-end direction.
Longitudinal Behaviour	$0.694 \times \text{Centroid Longitudinal CV} - 0.686 \times \text{Centroid Longitudinal Displacement}$	Superior scores may indicate greater range of displacement in the end-to-end direction with positioning in the reference teams' forward attacking half.

IMA, Inertial movement analysis; CV, Coefficient of Variation; SaEn, Sample Entropy; Rho, Cluster Phase.

Statistical Analysis

For offensive and defensive periods, only phases with a duration of 12 seconds or more were included in the analysis as this is believed to be the minimum timescale required for stable patterns of interpersonal coordination to emerge in the context of team sports. (22) Due to their unpredictable nature, a lower threshold was adopted for contested plays with phases spanning three seconds or more being included. (22) All set shot, umpire stoppage and goal reset phases were included, regardless of their duration. Outliers were also investigated for each variable via an outlier labelling rule of the interquartile range multiplied by 2.2. (14) Outliers identified via this rule were then investigated manually to

determine potential causes and assess whether they were realistic values or produced by measurement or other error. Due to the inherent variability in behaviour that exists between matches, a binomial Generalised Mixed Effects Regression model was used to estimate the associations between phase duration, physical and spatiotemporal variables (table 2) and the probability of a successful outcome in different phases of play. The competition round was included as a random effect while physical and spatiotemporal sum scores along with duration were added as fixed effects. Duration was not included as a fixed effect in umpire stoppages, goal resets or set shots as time spent in these phases of play are not necessarily in the players' control. Model outputs (odds ratios and their confidence intervals), Aikake Information Criterion (AIC) and pseudo 'variance explained' (R²) values were calculated to assess model goodness-of-fit. Goodness-of-fit was interpreted using Cohen's recommendations (r²: 0.02 = weak, 0.13 = moderate, 0.26 = substantial).(7) All statistical analyses were conducted using the lme4 (4) package in R statistical software (31) with significance values set at p<0.05.

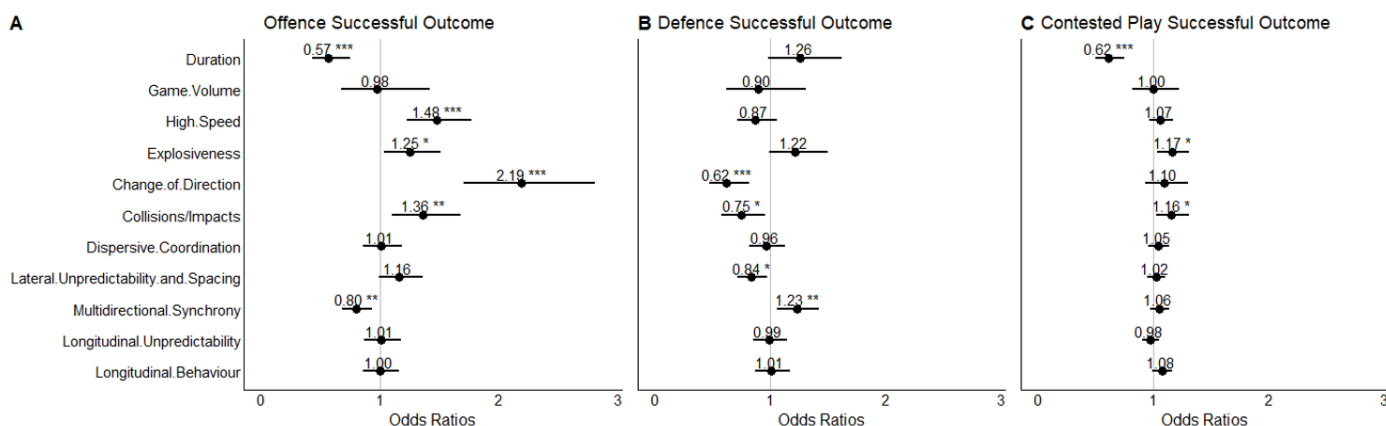
RESULTS

Outliers were detected, however, investigation revealed that these were realistic values rather than measurement errors. A select number of phases containing extreme values were visually assessed to determine whether values were realistic. Further, there were a large number of labelled outliers (n; 31% of total observations) which can likely be attributed to the inclusion of threshold variables such as high-speed running which have a relatively small median and interquartile range. The addition of fixed effects to a model that contained only the random intercept significantly improved the model fit for offensive, defensive, and contested phases of play but not for the other phases of play. Table 3 demonstrates the AIC for the null model and the specified model for each phase of play along with associated chi-square and p-values. Marginal r² values (indicating explained variance from fixed effects only) and conditional r² (indicating explained variance from both fixed and random effects) are also included in Table 3. Further, the odds ratios (OR) and associated 95% confidence intervals are demonstrated in Figure 1.

Table 3 - Model properties for each individual phase.

Model	AIC random effect only	AIC fixed and random effects	(χ^2)	df	p-value	Marginal r ²	Conditional r ²
Offence	1218.4	1038.8	201.6	11	< .001	.28	.28
Defence	1122.3	1069.3	75.0	11	< .001	.13	.13
Contested Play	3771.6	3749.2	44.4	11	< .001	.02	.02
Set Shot For	247.0	252.2	14.7	10	.142	.10	.30
Set Shot Against	234.0	243.2	10.7	10	.378	.07	.36
Umpire Stoppage	1622.5	1627.9	14.5	10	.150	.02	.02
Goal Reset	478.10	486.4	11.8	10	.300	.12	.12

χ^2 = chi-squared value; df = Model degrees of freedom.



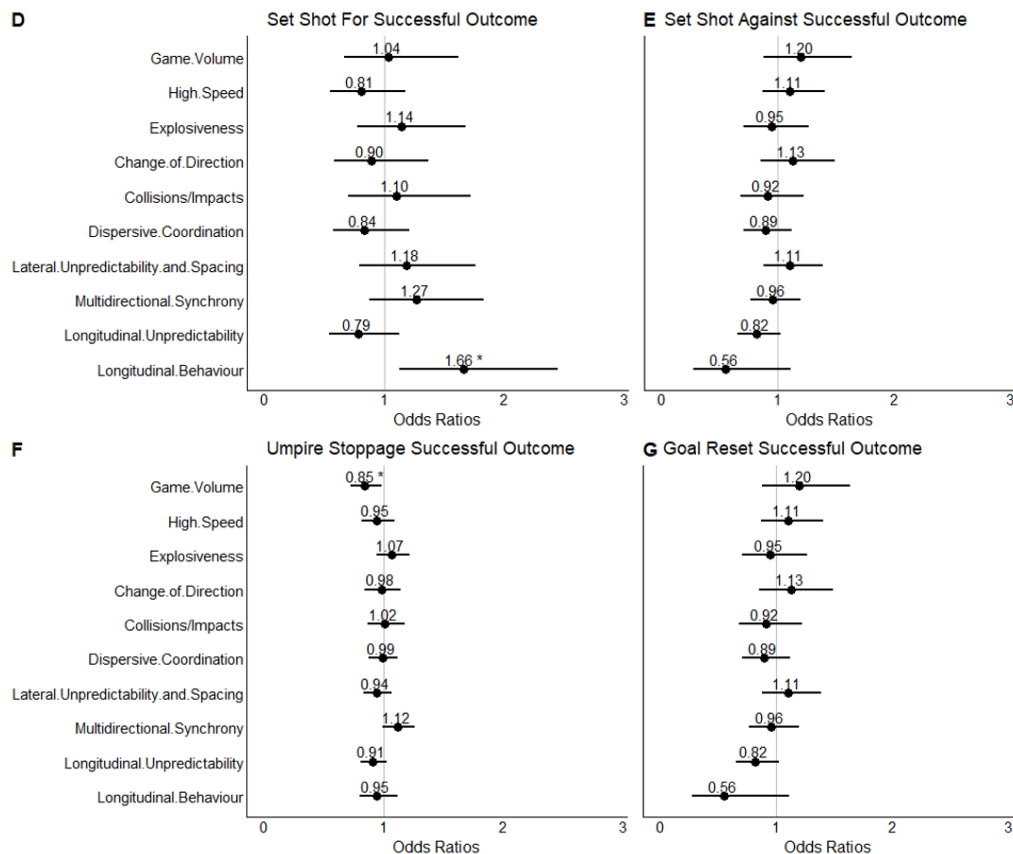


Figure 1 - Odds ratios and 95% confidence intervals demonstrating the likelihood of a successful outcome in each respective phase of play. Note: * < 0.05, ** < 0.01, *** < 0.001.

DISCUSSION

While a plethora of physical and spatiotemporal data is available for performance analysis in Australian Football, only recently have these been objectively simplified with sum scores representing different constructs of Australian Football match play subsequently easing the interpretation of the available information. (26, 27) Despite these surrogate measures successfully delineating different phases of play and providing unique insights into match-play, (25) the influence of these metrics on performance outcomes was yet to be explored. Accordingly, the present study addressed this shortcoming providing insight into behavioural movement characteristics associated with successful outcomes in each phase of play. These results may subsequently provide direction for coaches and practitioners when contemplating tactical strategies to be used during competitive games or developing tactical behaviour through specific training exercises.

Reduced duration accompanied by superior physical output, as defined by high speed, change of direction and collisions/impacts, and reduced multidirectional synchrony and, to a lesser degree, lateral unpredictability and spacing, contributed substantially to a model predicting successful offensive phase outcomes. As demonstrated in contextually similar sports such as soccer, the ability of attacking players to move quickly and unpredictably may assist in providing scoring opportunities. (18) This behaviour may help create misalignments with opposing defenders subsequently perturbing defensive formations or providing opportunities to get into free space to receive possession from teammates inside the forward 50 arc. (18) Alternatively, these movement behaviours may emerge as a result of a direct style of play with attackers quickly playing on from marked possessions in an attempt to sufficiently perturb defensive lines as it does not provide the defending team with enough time to modify their synergistic behaviours relative to the ball or the attacking team's movements. (33) The use of a refined definition of offensive success in the present study may explain why the current study's findings contradict those of Gronow et al. who revealed that lower physical output at higher speeds was associated with quarter success, implicating the use of slower playing style and controlled possession. (11) However, only examining phases of play with reference to quarter success may be limiting as favourable behaviours leading to specific positive outcomes such as a scoring opportunity may be negated or diluted across the timespan of a quarter. In contrast, the findings from the present study indicate a direct style of play or intense, asynchronous movement patterns that can effectively perturb defensive formations. Coaches and practitioners may be able to facilitate or afford these behaviours in a training setting using small sided games with more relative space per player (larger field sizes or lower player numbers) as this has shown to promote this style of behaviour in other contextually similar sports (1). For example, utilising a 16 V 16 format, instead of the regular 18 V 18, in a match simulation drill on an Australian Football field would provide approximately 60 m² extra of relative space per player (~460 m² vs ~520 m²). Alternatively, teams that achieve performance outcomes comfortably utilising this style of play in a training setting can be challenged by

decreasing the relative space per player or by using an outnumber scenario (e.g., 7 V 6 in defence and attack, respectively) as this may afford the offensive team with an environment whereby, they must exhibit more unpredictable behaviour to effectively exploit less space and receive possession. (1)

As revealed in other contextually similar sports, favourable defensive outcomes tend to contrast that of successful offensive behaviour. (18) In an Australian Football context, reduced physical output, as marked by lower change of direction and collisions/impacts values, and a tendency for increased duration contributed moderately to a model predicting favourable defensive outcomes. Subdued physical output, particularly alongside lower change of direction values, may also contribute to displays of superior multidirectional synchrony and inferior lateral unpredictability and spacing with players easing movement in an attempt to coordinate and synchronise movements to avoid being perturbed. (6) Further, the formation of a condensed defensive shape (lateral unpredictability and spacing) may help protect defensive zones and may also facilitate synchrony with smaller interpersonal distances between defenders providing favourable affordances to do so. (6) This condensed shape in defence was also implicated by Alexander et al. who revealed a positive association between reduced measures of dispersion and match outcome in a 15 V 15 match simulation drill. (2) Alternatively, these behavioural outcomes may also reflect an ability of the defending team to minimise the threat of direct offensive styles of play, holding players up on the mark and slowing down offensive passages of play. Contrary to drill designs that promote favourable attacking behaviours, i.e. direct and unpredictable styles of play, coaches can incorporate small sided games with less relative space per player to facilitate these favourable behaviours or alternatively, increase relative space per player to challenge the defensive unit. (1)

While physical and spatiotemporal characteristics were able to model successful outcomes in offensive and defensive phases of play (i.e., moderate-substantial), despite reaching a $p < 0.05$ threshold of significance, these characteristics were not as useful for explaining the variances evident in successful and unsuccessful outcomes in contested phases of play ($R^2 = \text{weak}$). Regardless, as per offensive phases of play, success in this phase of play may be a result of heightened physical intensity as marked by reduced duration and increased explosiveness and collisions/impacts. This behaviour may be a result of players changing velocity rapidly, physically shoving other players in the process, to be first to a loose ball or successfully follow the unpredictable movement of the ball. However, given the unpredictable nature of the phase only 2% of the variance in successful outcomes could be attributed to the included physical and spatiotemporal characteristics. The seemingly random nature may make it difficult to provide distinct guidelines for achieving success in this phase or, alternatively, technical and skill components (not assessed in the current line of enquiry) may be of greater importance for success during these passages of play. Similarly, during set-shots, goal-resets and umpire stoppages, physical metrics were not associated with success which may be attributed to the lack of a technical skill assessment. Future lines of enquiry should look at concurrently incorporating physical, spatiotemporal, and technical characteristics of team performance, including how their interaction may influence performance, to provide a more holistic perspective on Australian Football Performance.

While the present study can be considered comprehensive (i.e. incorporating novel metrics derived from over 70 physical and spatiotemporal variables), inclusion of technical indicators such as the number of passes or specific player interactions through cooperative network analyses may provide additional insight into behaviour leading to successful and unsuccessful phase outcomes. (26) Further, while definitions of successful phases were derived from discussions with coaching staff (Average AFL coaching experience = 6.8 years; Average professional playing experience = 11.5 years) there may be additional ways to delineate success and therefore model the data. This study also falls short in its ability to explore how movement behaviour evolves over different timescales with time providing unique affordances and likely influencing phase outcomes, which offers valuable avenues of research for future studies. (22) Lastly, while the random effect (competition round) failed to meaningfully account for any additional variance in the models, this may be indicative of tactical 'strengths' or 'habits' that are likely coached and remain stable across the season. Future investigations should consider pre-conceived tactical/coaching strategies and the influence this may have on behaviour on different phases of play. Regardless, the present study provides novel insights into factors influencing successful outcomes, particularly in offensive and defensive phases of play. Coaches and practitioners may use this information to develop tactical behaviour to optimise performance success and to manipulate training environments to afford specific behavioural outcomes.

PRACTICAL APPLICATIONS

- Reduced duration accompanied by superior physical output and lower measures of synchrony and predictability appear to be important for success in offensive phases of play due to the ability of attacking players to move quickly and unpredictability to perturb defensive formations and provide scoring opportunities. Alternatively, lower physical output and increased measures of synchrony and predictability may be important for defensive success and reflect an ability to slow opposition offensive sequences of play and coordinate movement to avoid disruptions in defensive formations. Accordingly, the association of specific physical and spatiotemporal sum scores with successful outcomes in certain phases of match-play indicate that these metrics may be useful for reviewing performance in these phases of play.
- Duration may be an important consideration for game plan design as this variable appears to influence offensive and, to a lesser degree, defensive outcomes. Time constraints applied in training drills may be manipulated to afford

more/less time in specific phases of play which may challenge players with respect to their physical requirements, synchrony and coordination. For example, implementing a 30-second shot clock whereby the attacking team only has 30 seconds to score when in possession of the ball may provide a suitable constraint to promote this direct behaviour.

- While there is little research examining change of direction characteristics in Australian Football, this variable may be of greater importance than traditional linear velocity-based variables. Change of direction appears to be a stronger factor influencing offensive and defensive success and thus has novel implications for conditioning and drill design. Incorporating reactive agility drills that help develop this component or manipulating match simulation drills to provide less relative space per player may encourage players to exploit change of direction ability, e.g., 11 V 11 instead of a 9 V 9 performed on half an Australian Football field and may be warranted given the association with success in the present study.

CONCLUSION

This was the first study to concurrently examine differences in physical and spatiotemporal characteristics with respect to successful outcomes in different phases of play in professional Australian football. Reduced duration accompanied by superior physical output, as defined by high speed, change of direction and collisions/impacts, and reduced multidirectional synchrony were deemed meaningful for explaining some successful offensive phase outcomes. This may be a result of a direct style of play with players moving erratically and unpredictability to misalign defenders or providing passing opportunities for teammates. In contrast, defensive success was characterised by reduced physical output, as demonstrated by change of direction and collisions/impacts, lower lateral unpredictability and spacing and increased multidirectional synchrony. This may be a result of players slowing movement in an attempt to coordinate and synchronise movements to avoid being perturbed. Findings from the present study provide novel insight for coaches and practitioners and potentially implicating training and game plan designs. Future research should consider including skill indicators into these models as well as the influence of specific player interactions (passing network characteristics).

ACKNOWLEDGEMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors and there were no conflicts of interest.

REFERENCES

1. Davids, K., Araújo, D., Vilar, L., Renshaw, I., & Pinder, R. An ecological dynamics approach to skill acquisition: implications for development of talent in sport. **Talent Development and Excellence**. 5: 21-34. 2013.
2. Sullivan, C., Bilsborough, J.C., Cianciosi, M., Hocking, J., Cordy, J.T., & Coutts, A.J. Factors affecting match performance in professional Australian football. **International Journal of Sports Physiology and Performance**. 9: 561-566. 2014.
3. Gronow, D., Dawson, B., Heasman, J., Rogalski, B., & Peeling, P. Team movement patterns with and without ball possession in Australian Football League players. **International Journal of Performance Analysis in Sport**. 14: 635-651. 2014.
4. Kempton, T., Sullivan, C., Bilsborough, J.C., Cordy, J., & Coutts, A.J. Match-to-match variation in physical activity and technical skill measures in professional Australian Football. **Journal of Science and Medicine in Sport**. 18: 109-113. 2015.
5. Hiscock, D., Dawson, B., Heasman, J., & Peeling, P. Game movements and player performance in the Australian Football League. **International Journal of Performance Analysis in Sport**. 12: 531-545. 2012.
6. Robertson, S., Back, N., & Bartlett, J.D. Explaining match outcome in elite Australian Rules football using team performance indicators. **Journal of sports sciences**. 34: 637-644. 2016.
7. Sullivan, C., Bilsborough, J.C., Cianciosi, M., Hocking, J., Cordy, J., & Coutts, A.J. Match score affects activity profile and skill performance in professional Australian Football players. **Journal of Science and Medicine in Sport**. 17: 326-331. 2014.
8. Araujo, D. & Davids, K. Team Synergies in Sport: Theory and Measures. *Front Psychol*. 7: 1449. 2016.
9. Bauer, A.M., Young, W., Fahrner, B., & Harvey, J. GPS variables most related to match performance in an elite Australian football team. **International Journal of Performance Analysis in Sport**. 15: 187-202. 2015.
10. Johnston, R., Watsford, M., Pine, M., Spurrs, R., Murphy, A., & Pruyn, E. Movement demands and match performance in professional Australian football. **International journal of sports medicine**. 33: 89-93. 2012.
11. Mooney, M., O'brien, B., Cormack, S., Coutts, A., Berry, J., & Young, W. The relationship between physical capacity and match performance in elite Australian football: a mediation approach. **Journal of Science and Medicine in Sport**. 14: 447-452. 2011.
12. Gray, A.J. & Jenkins, D.G. Match analysis and the physiological demands of Australian football. **Sports Medicine**. 40: 347-360. 2010.
13. Varley, M.C., Gabbett, T., & Aughey, R.J. Activity profiles of professional soccer, rugby league and Australian football match play. **Journal of sports sciences**. 32: 1858-1866. 2014.
14. Rennie, M., Watsford, M., Kelly, S., Bush, S., Spurrs, R., & Austin, D. PHASES OF MATCH-PLAY IN PROFESSIONAL AUSTRALIAN FOOTBALL: DISTRIBUTION OF. **The Influence of the Phases of Match-Play on the Physical, Technical and Tactical Profiles of Professional Australian Football**. 70. 2017.
15. Sheehan, W.B., Tribolet, R., Fransen, J., Novak, A., & Watsford, M.L. An assessment of physical and spatiotemporal behaviour during different phases of match play in professional Australian Football. **Journal of sports sciences**. (In Press). 2021.
16. Alexander, J.P., Spencer, B., Mara, J.K., & Robertson, S. Collective team behaviour of Australian Rules football during phases of match play. **Journal of sports sciences**. 1-7. 2018.
17. Silva, P., Aguiar, P., Duarte, R., Davids, K., Araújo, D., & Garganta, J. Effects of pitch size and skill level on tactical behaviours of Association Football players during small-sided and conditioned games. **International Journal of Sports Science & Coaching**. 9: 993-1006. 2014.
18. Richardson, M., Garcia, R.L., Frank, T.D., Gregor, M., & Marsh, K.L. Measuring group synchrony: a cluster-phase method for analyzing multivariate movement time-series. **Frontiers in physiology**. 3: 405. 2012.
19. Couceiro, M.S., Clemente, F.M., Martins, F.M., & Machado, J.a.T. Dynamical stability and predictability of football players: the study of one match. **Entropy**. 16: 645-674. 2014.
20. Kahn, J.H. Factor analysis in counseling psychology research, training, and practice: Principles, advances, and applications. **The counselling psychologist**. 34: 684-718. 2006.

21. Sheehan, W.B., Tribolet, R., Spurrs, R., Fransen, J., Novak, A.R., & Watsford, M.L. Simplifying the complexity of assessing physical performance in professional Australian football. **Science and Medicine in Football**. 1-8. 2020.
22. Sheehan, W.B., Tribolet, R., Watsford, M.L., Novak, A.R., Rennie, M., & Fransen, J. Tactical analysis of individual and team behaviour in professional Australian Football: Original investigation. **Science and Medicine in Football**. 2021.
23. Rennie, M.J., Watsford, M.L., Spurrs, R.W., Kelly, S.J., & Pine, M.J. Phases of match-play in professional Australian Football: Descriptive analysis and reliability assessment. **Journal of Science and Medicine in Sport**. 21: 635-639. 2018.
24. The Mathworks, I. MATLAB and Statistics Toolbox 2018a. Natick, Massachusetts, United States. 2018.
25. Henderson, M.J., Fransen, J., Mcgrath, J.J., Harries, S.K., Poulos, N., & Coutts, A.J. Individual Factors Affecting Rugby Sevens Match Performance. **International journal of sports physiology and performance**. 1-22. 2018.
26. Ric, A., Hristovski, R., Gonçalves, B., Torres, L., Sampaio, J., & Torrents, C. Timescales for exploratory tactical behaviour in football small-sided games. **Journal of sports sciences**. 34: 1723-1730. 2016.
27. Hoaglin, D.C. & Iglewicz, B. Fine-tuning some resistant rules for outlier labeling. **Journal of the American Statistical Association**. 82: 1147-1149. 1987.
28. Cohen, J. A power primer. **Psychological bulletin**. 112: 155. 1992.
29. Bates, D., Mächler, M., Bolker, B., & Walker, S. Fitting linear mixed-effects models using lme4. **arXiv preprint arXiv:1406.5823**. 2014.
30. Team, R.C. R: A language and environment for statistical computing. Vienna, Austria. 2013.
31. Memmert, D., Lemmink, K.A., & Sampaio, J. Current approaches to tactical performance analyses in soccer using position data. **Sports Medicine**. 47: 1-10. 2017.
32. Travassos, B., Vilar, L., Araújo, D., & McGarry, T. Tactical performance changes with equal vs unequal numbers of players in small-sided football games. **International Journal of Performance Analysis in Sport**. 14: 594-605. 2014.
33. Aguiar, M., Gonçalves, B., Botelho, G., Lemmink, K., & Sampaio, J. Footballers' movement behaviour during 2-, 3-, 4-and 5-a-side small-sided games. 33: 1259-1266. 2015.
34. Clemente, F., Santos-Couceiro, M., Lourenço-Martins, F., Sousa, R., & Figueiredo, A. Intelligent systems for analyzing soccer games: The weighted centroid. **Ingeniería e Investigación**. 34: 70-75. 2014.