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Space–time coordination dynamics in basketball: Part 2. The interaction between the two teams

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Abstract

In this article, we examine the space–time coordination dynamics of two basketball teams during competition. We identified six game sequences at random, from which the movement data of each player were obtained for analysis of team behaviours in both the longitudinal (basket-to-basket) and lateral (side-to-side) directions. The central position of a team was measured using its spatial (geometric) centre and dispersion using a stretch index, obtained from the mean distance of team members from the spatial centre. Relative-phase analysis of the spatial centres demonstrated in-phase stabilities in both the longitudinal and lateral directions, with more stability in the longitudinal than lateral direction. As anticipated, this finding is consistent with the results of an analysis of individual playing dyads (see companion article, this issue), as well as the more general principle of complex systems conforming to similar descriptions at different levels of analysis. Phase relations for the stretch index demonstrated in-phase attraction in the longitudinal direction and no attraction to any values in the lateral direction. Finally, the difference between the two stretch indexes at any instant showed phase transitions between two stable patterns when the difference was represented in binary form. This result is attributed to the reciprocity between teams in their amounts of expansion and contraction when possession of the ball is won and lost.

Keywords: *Patterns, couplings, dynamical systems, interpersonal coordination, perturbation*

Introduction

In a companion article (Bourbousson, Sève, & McGarry, 2010), we report an investigation of space–time patterns of basketball players in terms of the intra- and inter-couplings present among the entire set of player dyads. The collective product emerging from these multiple interactions was reasoned to produce game behaviour. This interpretation is consistent with the earlier suggestion of McGarry and colleagues (McGarry, Anderson, Wallace, Hughes, & Franks, 2002), who proposed a common description for sports behaviour, from individual sports (one vs. one) comprising a single dyad to team sports (many vs. many) comprising multiple dyads. In fact, the game behaviour in team sports might be investigated as a consequence of dyad interactions at different levels of analysis, from a player–player dyad at the lowest level through to a team–team dyad at the highest level. This view is informed by, and consistent with, the principle of universality for complex systems, which states that a complex system will subscribe to similar descriptions on different levels of analysis and time scales (Kelso, 1995). In our companion article, we analyse the interactions of player–player dyads during a game of basketball. In this article, we examine the same basketball contest but analyse the interaction between teams, with each team considered a separate collective entity as a result of interactions between team members. This view of a team as a single entity is consistent with the suggestion that a social unit is the self-organizing result of individuals cooperating with each other towards some common goal (Marsh, Richardson, Baron, & Schmidt, 2006).

Previous investigations of sports contests as dynamical self-organizing systems have targeted the sports of squash (McGarry, 2006; McGarry & Walter, 2007) and tennis (Palut & Zanone, 2005) for formal analysis. In both the present study and our companion article (Bourbousson et al., 2010), we extend these investigations of individual sports as dynamical systems to team sports using basketball. In all of these investigations, a sports contest is considered on the basis of coupled oscillator dynamics in which the self-organizing patterns emerge as a result of exchanges of information

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within the dyad. This consideration of sport behaviour was informed by the theoretical contributions of Kelso and colleagues, who developed a formal dynamical coupled oscillator explanation that accounted for the coordinated behaviour of human rhythmic actions (Haken, Kelso, & Bunz, 1985; for a review of dynamical systems, see Kelso, 1995). Other sports attracting research on behaviour in the context of dynamical systems, although not necessarily predicated on the presence of coupled oscillators, include boxing (Hristovski, Davids, & Araujo, 2006), basketball (Schmidt, O'Brien, & Sysko, 1999), soccer (Davids, Araujo, & Shuttleworth, 2005; Frencken & Limmink, 2008), and rugby union (Passos et al., 2008).

Methods

The research was conducted in accordance with accepted standard research practice in France as well as the guidelines outlined in the Canadian Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans.

Data collection

The player movement data reported in our companion article (Bourbousson et al., 2010) formed the basis for data analysis reported here. As with the companion article, a description of the game score dynamics (upper panel), the location of the data sequences extracted with reference to the game score (upper panel), and a description of the important game events within these sequences (lower panel) is provided in Figure 1.

Data processing: The spatial centre and the stretch index

Two separate metrics were identified to obtain a measure of team behaviour in basketball. First, the longitudinal (basket-to-basket) and lateral (side-to-side) data from each of the five players on a given team were reduced separately to their spatial centres. The mean data from the five players were used to represent the spatial centre for each team as each player then contributes equal information to the team metric. The relative-phase between the spatial centres of the two teams was then computed using the Hilbert transform (Palut & Zanone, 2005) for both the longitudinal and lateral displacements.

The second metric used was the stretch index, which measures the expansion or contraction of space in the longitudinal and lateral directions that a team demonstrated as the game unfolded. The stretch index for the longitudinal and lateral directions was obtained by computing the mean of the distances between each player and the spatial centre for that team. Thus, the stretch index represents the mean deviation of each player in a team from the spatial centre. Once again, the relative-phase of the stretch indexes was computed using the Hilbert transform to account for the interaction between the two teams.

Figure 2 depicts example representations of playing configurations from which the spatial centres and the stretch indexes for each team might be obtained. The players on one team are represented by solid grey circles and the players on the other team by solid black circles, with the spatial centre of each team similarly being represented by solid grey and black squares, respectively. The stretch indexes in the longitudinal and lateral directions for a team are obtained from the mean of the vertical and horizontal line distances (not shown) extending from the spatial centres to each of the players on that team.

Results and discussion

Spatial centres: Relative-phase analysis

Figure 3 demonstrates the displacements of the spatial centres of the two teams in the longitudinal (upper left panel) and lateral (upper right panel) directions from a single basketball sequence, with the black and grey lines representing Team A and Team B, respectively. Note that the longitudinal data demonstrate that the defending team reverses direction a little before the attacking team as the teams traverse between the two baskets in periodic fashion because of changes in ball possession. Even so, the displacement data demonstrate that each team oscillates in both the longitudinal and lateral directions, with strong coupling tendencies between the teams being observed, particularly in the longitudinal direction (middle panels). Similar findings using the longitudinal and lateral data combined have been reported for small-sided (5 vs. 5) soccer games (Frencken & Lemmink, 2008), providing evidence that the space–time dynamics of team–team dyads extend across sports. The middle panels represent the phase relations of the displacement data for the basketball team sequence depicted in the upper panels. The phase relations in the longitudinal direction demonstrate strong attractions towards in-phase (mean $= 6.9^\circ$, SD $= 10.5^\circ$), a finding that similarly extends to the lateral direction albeit with more variability (mean $= -4.9^\circ$, SD $= 39.9^\circ$). The data presented in Figure 3 are unforced, whereas the means and standard deviations reported were computed on relative-phase data forced between -180° and 180° limits.

Visual inspection of the lateral displacement data (upper right panel, Figure 3) reveals three separate divergences between the two teams in the

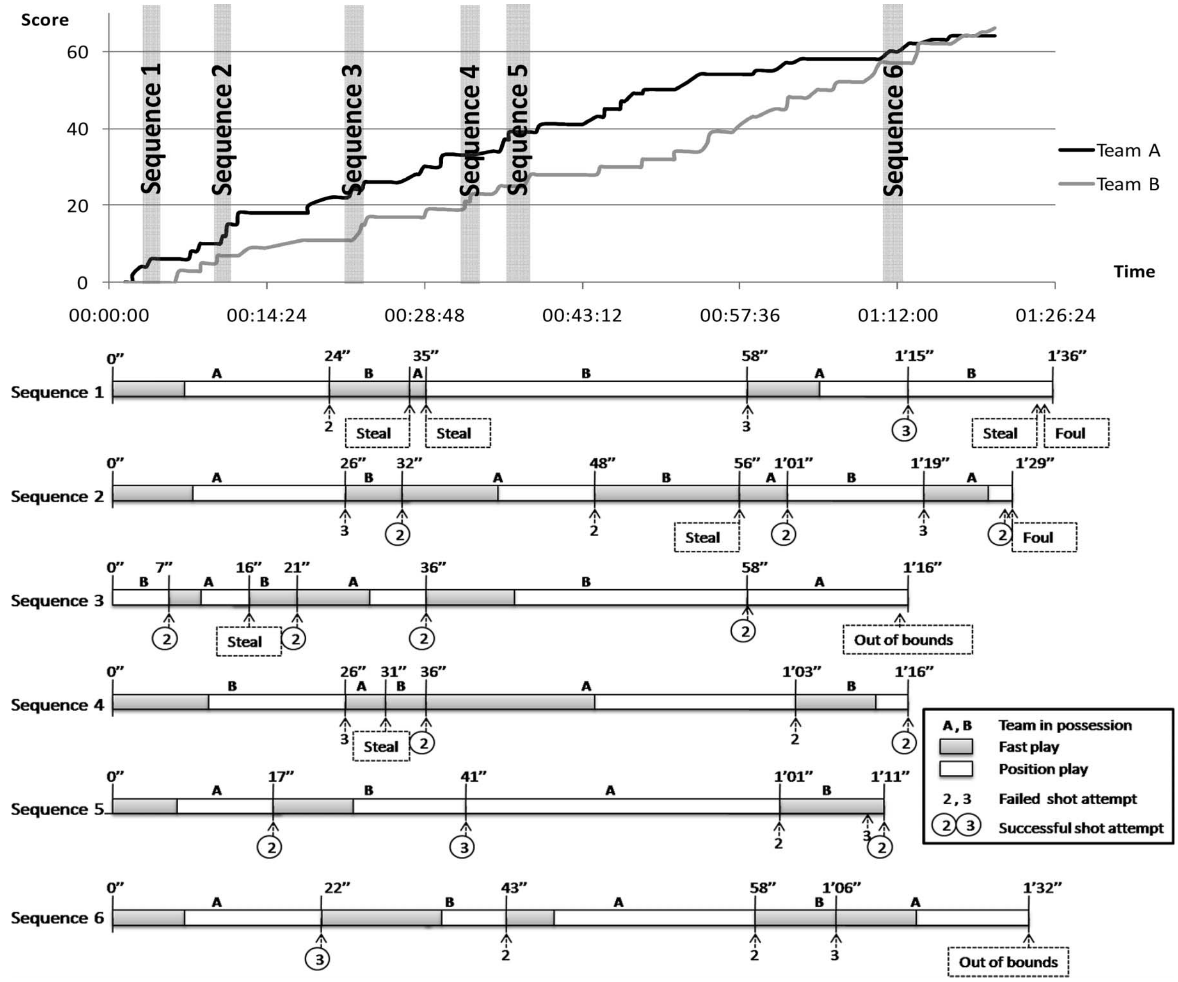

Figure 1. Time line of the changing game score and location of the data sequences extracted for analysis (upper panel). The individual data sequences and the time line of important game events, including team in possession, type of play, shot attempts, steals, fouls, and out of bounds (lower panel).

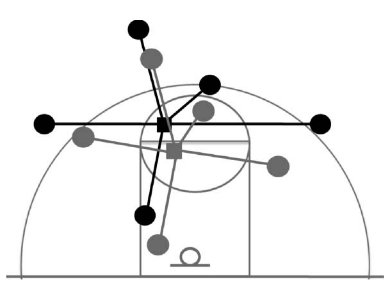

Figure 2. Representation of the spatial centre and the stretch index for each team. Solid circles represent the players on the two teams (grey and black). Solid squares represent the spatial centre of each team. Line distances extending from the spatial centres to each of the respective players represent each player's contribution to his team's stretch index.

mid-section of the basketball sequence. These divergences occur when one team changes direction a short time before the other team. The first divergence disrupts the phase relation and causes instability thereafter, as noted in the increased variability as the phase relation progresses gradually through one cycle (middle right panel). This disruption from in-phase might be considered as a perturbation in the game sequence, a perturbation being defined by McGarry and colleagues (McGarry, Khan, & Franks, 1999) as a destabilization of the phase relation from which the system either restabilizes some time thereafter or otherwise remains destabilized up to some outcome. If perturbations disrupt the balance of a system to the advantage of one player/team at the expense of the other, then they constitute key aspects of sports behaviour.

In terms of a behavioural description for this game sequence, possession of the ball is with Team B (Figure 1, lower panel, sequence 5) when the first divergence occurs (Figure 3, upper right panel). This possession results in a successful 3-point basket at the second divergence (41 s) when ball possession is exchanged. Team A then retains possession until 61 s when ball possession is returned to Team B by means of an unsuccessful 2-point attempt. This

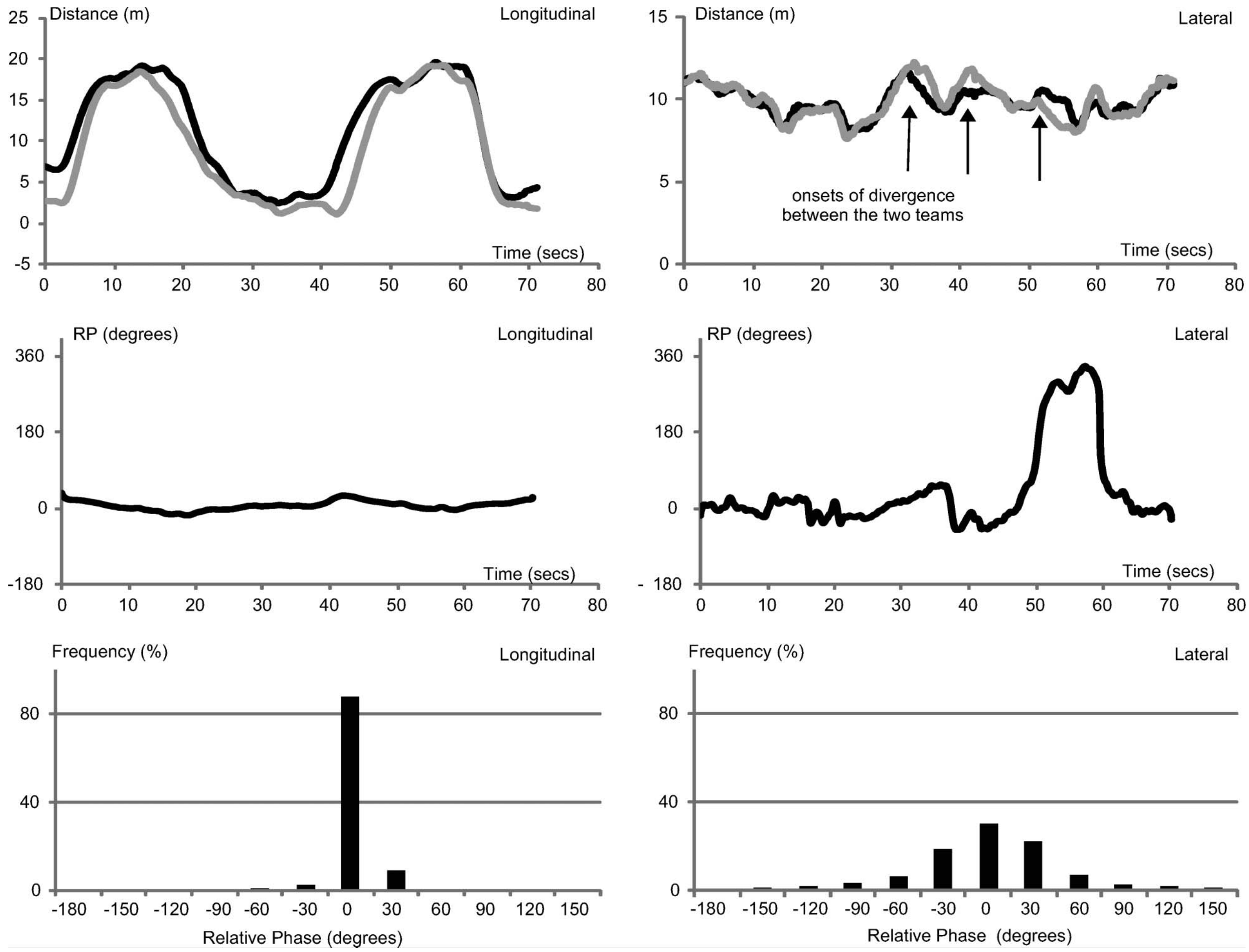

Figure 3. Relative-phase (RP) analysis between the spatial centres of the two basketball teams, presenting unfiltered data of displacements and relative-phase dynamics from a single sequence, and frequency histograms of the overall relative-phases. The direction (longitudinal or lateral) is located on each panel.

game event is marked in the relative phase data by a return to stability with the game sequence ending soon after with a successful 2-point basket for Team B, following an unsuccessful 3-point attempt a couple of seconds earlier.

The lower panels of Figure 3 represent the instantaneous phase relations between the two teams for all basketball sequences analysed. The data are presented as frequency histograms for the longitudinal and lateral displacements. The abscissa represents relative-phase displayed from -180° to 180° distributed into 30° bins. The first bin represents data from $-180 \pm 15^\circ$, the second bin represents data from $-150 \pm 15^\circ$, and so on through to the twelfth bin, which represents data from $150 \pm 15^\circ$. (*Note*: -195° through -181° equals 165° through 179° respectively due to the forcing of data into one cycle between -180° and 180°.) The ordinate represents the frequency of relative-phase occurrences within each bin.

The phase relation frequencies from all of the game sequences available confirm the above interpretations for a single game sequence. In the longitudinal direction, the two teams demonstrate a marked attraction to in-phase with little variation observed. This finding is unsurprising given that in basketball it is natural for both teams to travel the court together from basket to basket. Some attraction to in-phase is similarly observed in the lateral direction but the attraction is weaker. Furthermore, the symmetrical variability about in-phase for the lateral data demonstrates repulsion from anti-phase, as expected. Together with the results from the player–player dyads reported in our companion article, the results from the team–team dyad reported here demonstrate that basketball game behaviour subscribes to a common dynamical description. The anti-phase tendencies in the lateral direction of the two wing players on a basketball team reported by Bourbousson et al. (2010), and the repulsions from anti-phase of the team–team dyad reported in this article, furthermore exemplify the point that a common description need not necessarily mean the same description (Kelso, 1995).

Stretch indexes: Relative-phase analysis

Figure 4 (upper panels) presents the stretch index measures of the two teams from the same single basketball sequence in both the longitudinal (left panel) and lateral (right panel) directions. The middle panels represent the phase relations for these stretch indexes with some stabilities observed in the longitudinal direction only. The lower panels represent the frequency distributions of relative-phase observed across all game sequences for the longitudinal and lateral data. Once more, in-phase stability was observed in the longitudinal direction only, with no evidence for attractions to preferred phase relations in the lateral direction. Thus, in addition to each team moving from basket to basket in unison (Figure 3), they tend to expand and contract together in this same direction too (Figure 4). We view this result as being consistent with expectations given the man-to-man marking strategies used by both teams. This interpretation does not extend to the lateral direction however, in which we had expected an anti-phase attraction, if the attacking team were to increase width and the defending team to reduce width in defence of the basket.

Stretch indexes: Relative stretch index analysis

To try and account for some of the high-frequency, low-amplitude fluctuations (noise) in the stretch index data, a relative stretch index was calculated from the difference between the stretch indexes of the two teams at any instant. The upper panels in Figure 5 present the same data as the upper panels in Figure 4. The middle panels represent the relative stretch indexes in both the longitudinal and lateral directions. Zero values indicate that both teams are stretched in equal measure, positive values indicate that Team A is more stretched than Team B, and negative values indicate that Team A is less stretched than Team B. The results illustrate that the relative stretch index changes intermittently between positive

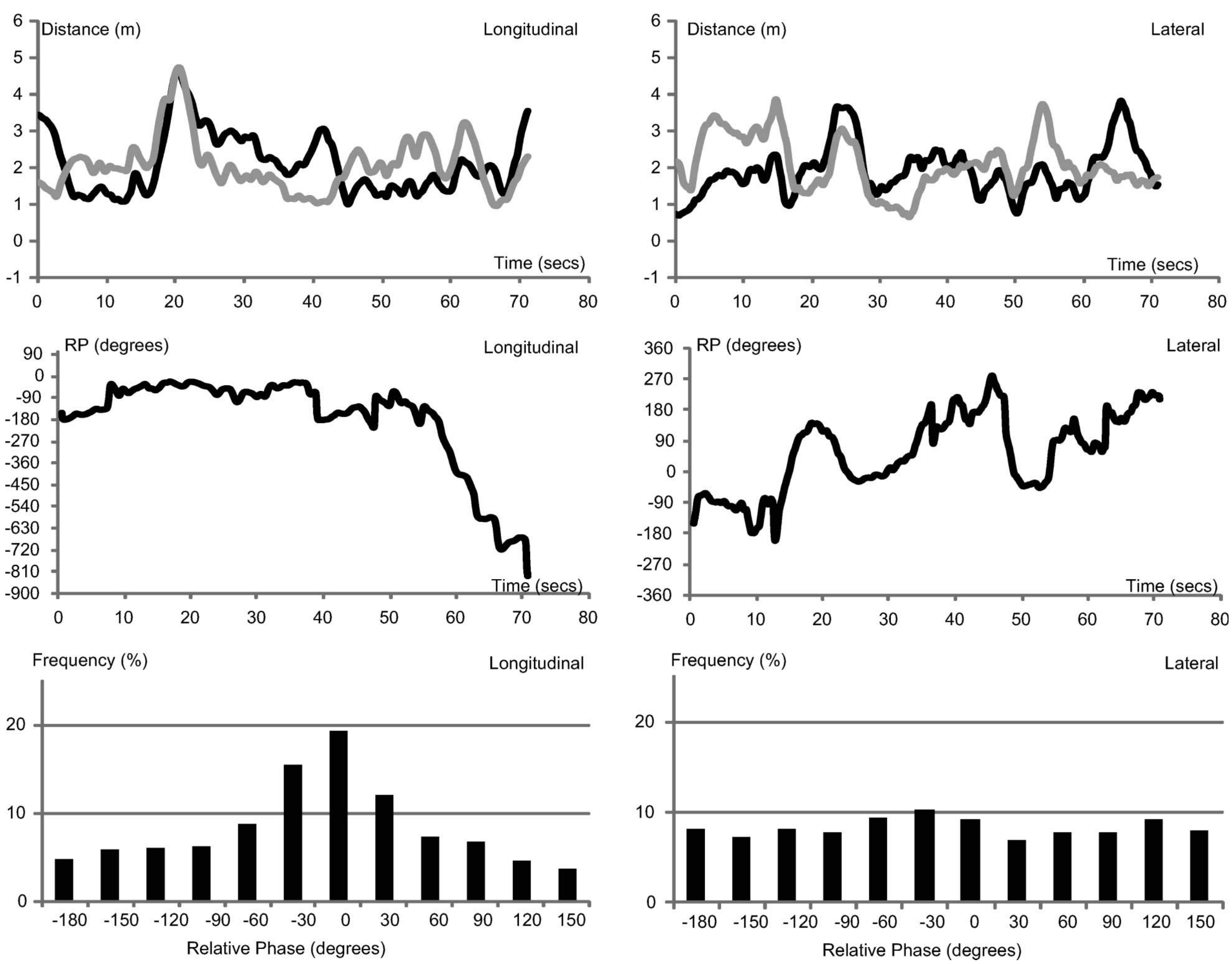

Figure 4. Relative-phase (RP) analysis between the stretch indexes of the two basketball teams, presenting unfiltered data of displacements and relative-phase dynamics from a single sequence, and frequency histograms of the overall relative-phases. The direction (longitudinal or lateral) is located on each panel.

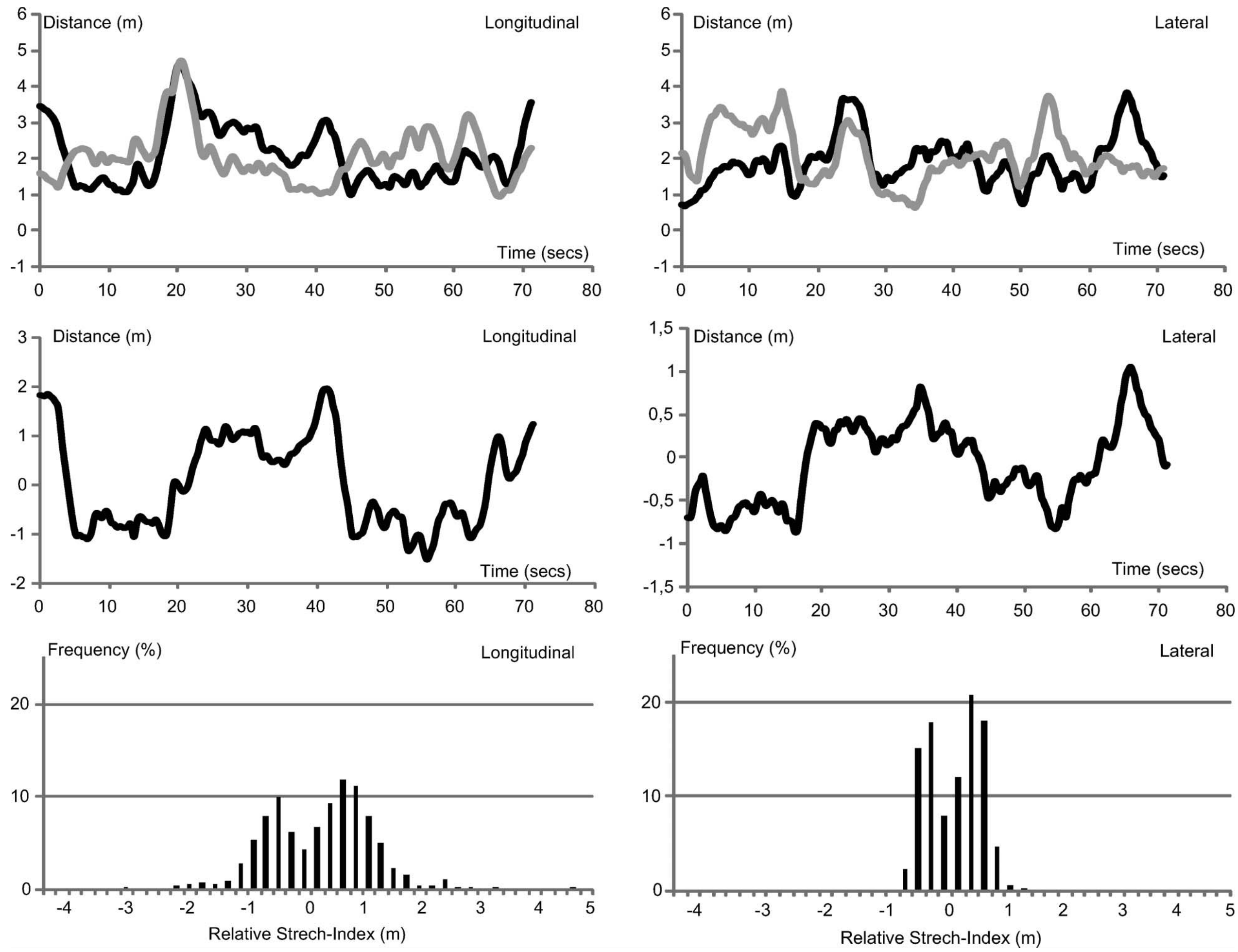

Figure 5. Relative stretch index (RSI) analysis between the two basketball teams, presenting unfiltered data of displacements and relative-phase dynamics from a single sequence, and frequency histograms of the overall relative stretch indexes. The direction (longitudinal or lateral) is located on each panel.

values and negative values in both the longitudinal and lateral directions. The lower panels confirm this intermittent switching by demonstrating evidence of bi-stability in both directions, a result of different amounts of expansion or contraction between the two teams as the teams attack and defend a given basket.

Figure 5 (lower panels) presents the frequency distributions of the relative stretch index measured across all game sequences for both the longitudinal and lateral directions. The relative stretch index frequency distributions exhibited two principal values for both the longitudinal (left panel, bins −0.4 m and 0.6 m) and lateral (right panel, bins −0.2 m and 0.4 m) directions, with stronger attractions observed in the lateral direction. These bi-stable distributions in both directions are explained by reference to the man-to-man marking strategies used by both teams. In this kind of defence, the basic principle for the defender is to position himself or herself between the attacker and the basket while maintaining a reasonable distance from the opponent so as to defend against him or her without making contact and risking a foul. If applied, this principle should produce smaller stretch indexes in both the lateral and longitudinal directions for the defending team and larger stretch indexes for the attacking team, resulting in the positive and negative values observed. Furthermore, the stretch index values at peak frequencies indicate the preferred distances used by each team when defending and attacking. Thus, the data revealed that Team A maintained shorter distances to the opponent when defending in both the longitudinal and lateral directions than Team B. The preferences to certain values of stretch index for both teams might be taken to indicate unique patterned behaviours for each team and their interactions.

Some considerations for game behaviour

Qualitative inspection of the video data game sequences by the first author, a basketball coach of national standard, revealed two classifications of shot attempts. The first classification was attributed to individual game play and the second classification to collective enterprise on the part of the attacking team. We refer to the first classification as an individual shot and the second classification as a team shot.

Figure 6 presents the relative-phases between the spatial centres for the two teams on both the lateral and longitudinal axes for two individual game sequences. The team in possession of the ball at any instant, and thus the changes in ball possession between the two teams, is reported in the boxes located between the lateral and longitudinal data for both panels. The shot attempts at basket and their classification are documented with black arrows in numbered sequence on the respective relative-phase data.

In the sixth sequence (upper panel), the first and fourth shots were classified as individual shots, a result of the defender being judged to allow the attacker too much space and in these instances

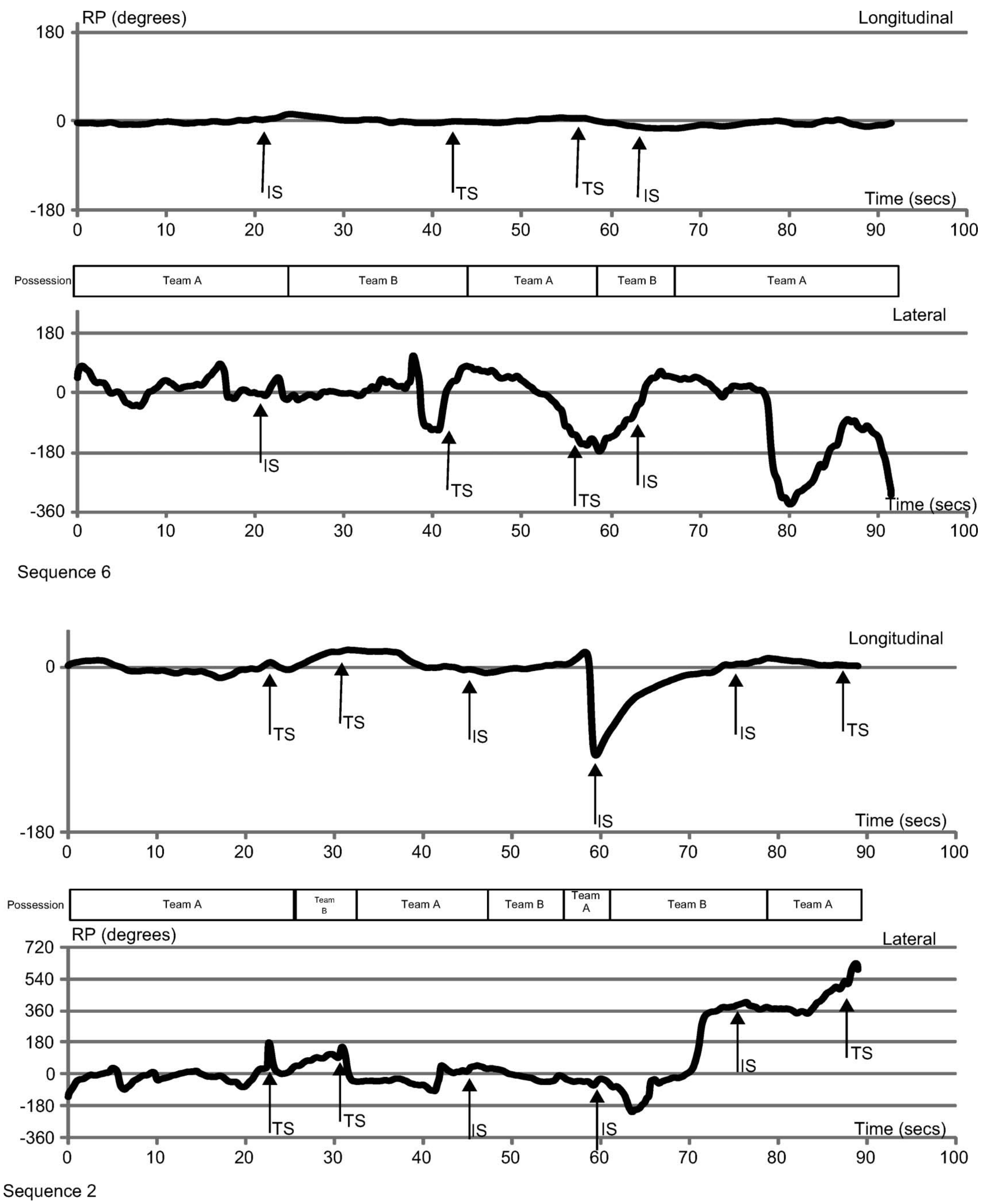

Figure 6. Relative-phase (RP) dynamics from single sequences related to shot attempts and changes in ball possession. The direction (longitudinal or lateral) is located on each panel.

allowing a shot attempt from long distance (i.e. 3-point shots). When an attacker exploits a defensive lapse within the attacker–defender dyad, no association between shot attempt and spatial centre relative-phase is predicted and, indeed, no association was observed. The fourth shot is interpreted as being made in the presence of an ongoing disruption in the lateral relative-phase. The second and third shot attempts were classified as team shots and disruptions in the lateral relative-phase were observed beforehand. With respect to changes in ball possession, investigation of the lateral and longitudinal relative-phase data uncovered no particular associations between these variables.

In the second sequence (lower panel), the first, second, and sixth shot attempts were classified as team shots. Once again, changes in lateral relative-phase are associated with these types of shot attempts. In the longitudinal direction, the relative-phase data once again showed tendencies to in-phase regardless of the team in possession of the ball. The exception to this observation of course is noted in the fourth shot, which was associated with a major shift in relative-phase. Subsequent investigations revealed a counter-attack in which Team A was able to take prompt advantage of an unexpected loss of possession by Team B. Indeed, the unexpected change in ball possession is the only example of possession exchanges in this game sequence not being the result of a shot attempt by one of the two teams (Figure 1, lower panel, second sequence). For this reason, these data offer the only example of a disruption in longitudinal relative-phase that is associated with a shot attempt.

The first two shots in the second game sequence coincided with minor disruptions from in-phase in the lateral direction. Visual inspection of the game behaviours indicated both shots were taken under good attacking conditions in which each shot was considered as being "open". Since these open shots occurred following local disturbances in relative-phase, it is possible that this particular arrangement represents an effective collective space–time dynamic for the attacking team. If so, this destabilization of relative-phase might be a good candidate for future research regarding an objective assessment of conditions in which open shot opportunities might be created.

Investigation of correspondence between game events and the relative stretch index showed that major variations in this collective variable corresponded with changes in ball possession. Figure 7 presents the relative stretch index for both the sixth sequence (upper panel) and the second sequence (lower panel). Once again, the time line of attempted shots at the basket is depicted with black arrows and the team in possession of the ball denoted in boxes. In addition, the relative stretch index is depicted in each chart in binary fashion to assist data interpretation. In this way, positive values of the relative stretch index are represented as unity (i.e. 1) and negative values as minus unity (i.e. -1) using the right ordinate. These binary values simply indicate the lengths of time that the relative stretch index is positive and negative, respectively.

When observed over the game sequences, the change of sign in the relative stretch index from positive to negative or vice versa occurred in the main shortly following change in ball possession. These results indicate that both teams respond to the exchange of ball possession by changing their shape structure in similar ways, for example by expanding or contracting together, but they do so at different rates of change depending on whether possession is won or lost. These considerations of contraction and expansion of the stretch index as a function of ball possession exchanges, apply at least with respect to what the other team is doing. We suggest that the interrelation between expansion and contraction is suitably expressed in the relative stretch index.

General discussion

We investigated the space–time dynamics of basketball game behaviour by analysing the interactions between teams using a spatial centre metric. Relative-phase analysis of the spatial centres indicated a strong in-phase relation between the two teams in both the longitudinal and lateral directions, especially the former. The stretch index metric was used as a measure of dispersion of the players in a given team from the spatial centre, thus providing an indication of whether a team was expanding or contracting at any instant. Relative-phase analysis of the stretch indexes noted an in-phase relation in the longitudinal direction only. In contrast, the introduction of a relative stretch index presented good evidence for bi-stable attractions in both the longitudinal and lateral directions. In fact, stronger attractions were expressed in the lateral direction than the longitudinal direction when the relative stretch index was used. These different results demonstrate clearly that the information obtained from the analysis is influenced by the particular indicator used.

The different metrics used assessed different properties of team behaviour. Indicators of the interactions between teams such as relative-phase and the difference measure express some characteristics of game behaviour but not others. The relative-phase data for the spatial centres, for example, contain important information with regard to the space–time relation between the teams as they traverse the basketball court in both the longitudinal and lateral directions. Further attempts to relate

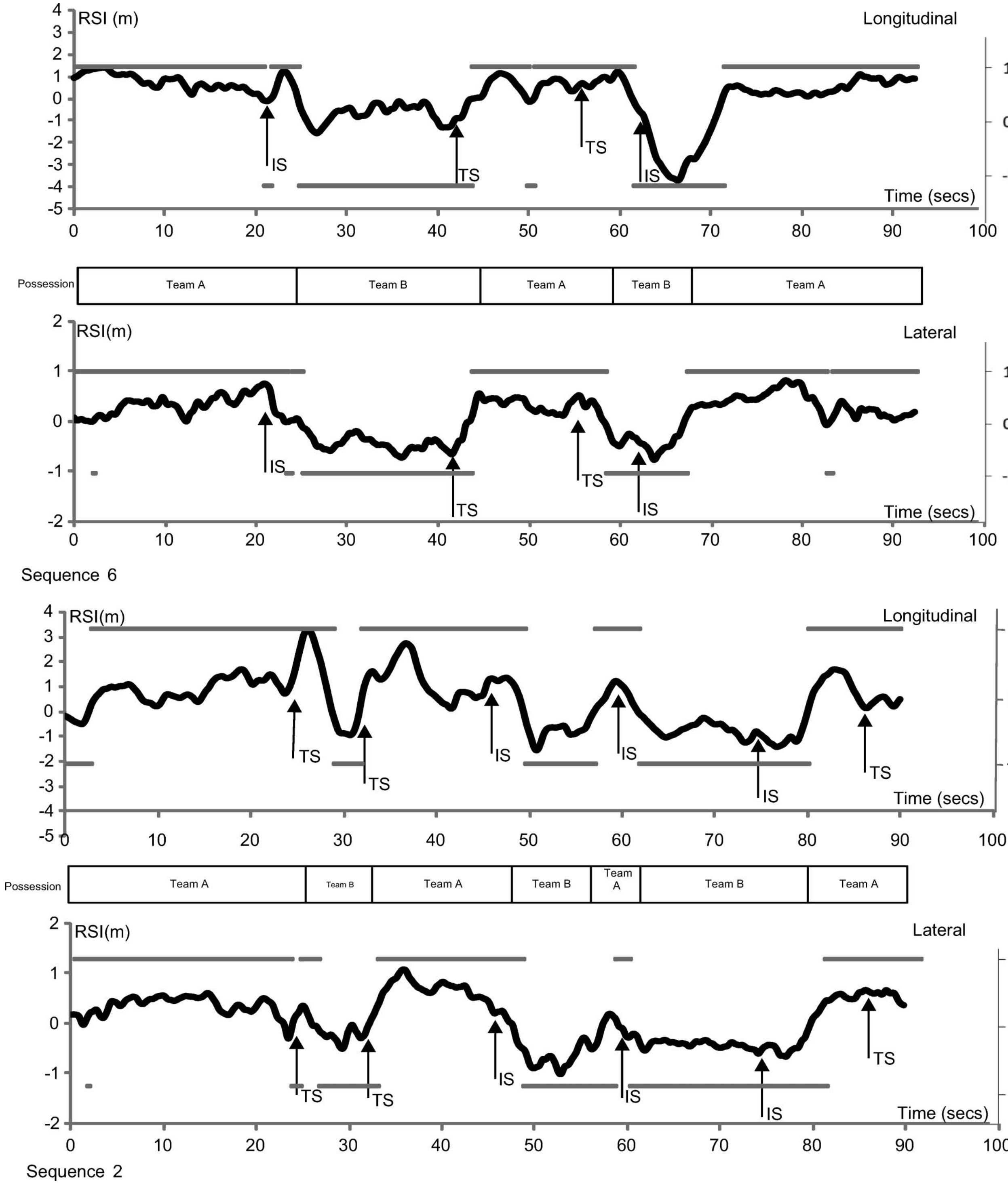

Figure 7. Relative stretch index (RSI) dynamics from single sequences related to individual shot (IS) and team shot (TS) attempts and changes in ball possession. The direction (longitudinal or lateral) is located on each panel.

these data with key aspects of game behaviour, such as shot attempts at the basket, ought to be an important undertaking in future research. In our preliminary investigation, we noted that the relative-phase between the spatial centres was sometimes disrupted at or around the time of a behavioural event to which it must presumably be related. This finding did not extend to the relative stretch index, although this particular metric was shown to be associated with ball possession exchanges. We propose the relative stretch index as a useful metric for sport performance analysis as it is a good descriptor of the interaction between teams as they expand and contract.

Shot attempts attributed to teamwork were produced seemingly just after disturbances in the relative-phase of spatial centres when measured in the lateral direction, and sometimes in both the longitudinal and lateral directions. This particular indicator might well contain useful information for sports practitioners if the dynamic structures that underpin the behavioural interactions can be better understood. Further research on the associations between the space–time dynamics and important game behaviours is required.

The use of a metric such as the spatial centre or the stretch index might be given further consideration in light of the individual players that comprise the team. For example, the spatial centre as defined in this article constitutes the mean position coordinates of the team without regard to the information content of each individual player. In other words, each player contributes equal information to the spatial centre as defined, which might be considered reasonable. On the other hand, it might also be reasonable to propose that players contribute unequal and changing information to the metric, their contribution being influenced by information such as the space the player can attack or defend, the offensive threat or defensive cover provided, and so on. The stretch index similarly constitutes a measure of the mean dispersion of players about the spatial centre without consideration of game context. Further work on developing appropriate performance metrics and investigating their space–time dynamics in association with important game behaviour is required.

Acknowledgements

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