

Scoring coordination patterns in basketball international championships of national teams

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SCORING COORDINATION PATTERNS IN BASKETBALL INTERNATIONAL CHAMPIONSHIPS OF NATIONAL TEAMS

KEYWORDS: time series, dynamical systems, complex systems, relative phase, Hilbert transform.

ABSTRACT: The performance of two basketball teams can be analysed by exploring their different scoring dynamics on the basis of the two time series representing the scoring process of each team throughout the game. Existing studies following this approach focused mainly on regular season and playoff games in different basketball leagues. The aim of this study was to conduct this type of analysis on games of National Teams championships, focusing specifically on final round close games, as those in which medals are decided and teams perform in a very similar level. The study considers the final round games (i.e. semi-finals games, third-place game and final game) of the main men's professional basketball International Championships of National Teams (i.e. European Championships, World Championships and Olympic Games) played during the period 2005-2013. Different methods of time series analysis were used (i.e. autocorrelation and cross-correlation functions, double backward moving averages, Hilbert transform). The results revealed an increasing scoring coordination pattern between the teams as the games unfolded, showing extremely high coordinated behaviours in the 3rd and 4th quarters (i.e. similar scoring streaks by the two teams; back-and-forth scoring patterns). This suggests that are the first two quarters of the games those leading to major fluctuations on the scoreboard (i.e. game periods in which one team's scoring performance is very successful whilst the other team's is not). This study may be matter of interest to coaches and performance analysts in the field of basketball, providing practical information for specific game preparations in International Championships of National Teams.

Previous research has analysed basketball performance from a time-dependent dynamic perspective in which the actions and the critical events are registered in connection with the game process. Existing studies have used different analysis techniques to analyse basketball players' and teams' performance from this time-dependent perspective (see Sampaio, Ibáñez and Lorenzo, 2013 for a comprehensive review). Within this topic of criticality, the performance of two basketball teams can be analysed by exploring their different scoring dynamics during the game on the basis of the two time series representing the scoring process of each team throughout the game. This analysis might provide valuable insights into the teams' scoring coordination patterns across the game by highlighting the potential critical periods in the game. In this sense, the identification of successful and less successful phases in the game constitutes a useful tool for modelling the interaction between two opposing teams from a practical perspective (Lames and McGarry, 2007). Existing studies following this approach in basketball focused mainly on regular season and playoff games in different leagues (e.g. García, Gómez, Cañadas and Ibáñez, 2015; Lorenzo, Sampaio and Ribero, 2005; both in Spanish ACB league). To the best of our knowledge there are no available studies that have specifically assessed the game-scoring coordination patterns of the teams in International Championships of National Teams (i.e. European

Championships, World Championships and Olympic Games). Performing this type of study could contribute to a better understanding of elite National Teams' behavior in these competitions. Specifically, in the final round games (i.e. semi-finals games, third-place game and final game) where medals are decided and wherein teams try to perform at their best level. In particular, those games ending with a close score difference (i.e. close games) represent the highest level of performance between two opposing teams and constitute an attractive and relatively unexplored field of analysis in team sports (DeSaá et al., 2012). Therefore, the aim of this study was to analyse the game-scoring coordination patterns of National Teams in top-level international championships, focusing specifically on final round close games.

Methods

Sample

The study considers the final round games (i.e. semi-finals games, third-place game and final game) of the main men's professional basketball International Championships of National Teams (i.e. European Championships, World Championships and Olympic Games) played during the period 2005-2013. Only those Championships from which the official play-by-play sheets were available were considered, for a total of seven tournaments (i.e.

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2005, 2007, 2009, 2011 and 2013 European Championship, 2010 World Championship and 2012 Olympic Games) and 28 games under analysis (four games per Championship: two semi-final games, one third-place game and one final game). 2006 World Championship and 2008 Olympic Games were not incorporated into the analysis due to the impossibility of obtaining their official play-by-play sheets. The final sample comprised 12 close games (mean differences in score of 4.5 ± 2.63 points; range 0-8 points). Two of these twelve close games ended with a tied score at the end of the playing time for the fourth game quarter (i.e. a basketball game is divided into four quarters of 10 minutes each, for a total playing time of 40 minutes), and therefore an extra period of five minutes was necessary to break the tie.

Procedure

The official play-by-play sheets of the twelve close games that comprised the final sample were downloaded from the open-access official websites of the Championships under study. The analysis of the patterns of coordination between the scoring processes of each pair of opposing teams was conducted on the basis of the two time series representing the scoring process of each team throughout the game (horizontal axis: game time; vertical axis: points scored) (Prieto, Gómez and Sampaio, 2015). In order to achieve high accuracy in the analysis, these scoring processes time series were recorded in a scale of 10-seconds time-intervals, for a total of 240 time-score records per team throughout the game (i.e. 40 minutes of game \times 6 records of 10-seconds per minute), with 30 time-score records added for each 5-minute extra period that is required (if any).

In a first step, the specific forms of persistence of the time series representing the scoring processes of the teams along the games were examined in the two following ways: (i) for each individual team (winner vs. loser) by computing the autocorrelation function (ACF) as measure of self-similarity, which refers to the correlation of a time series with its own values (Brockwell and Davis, 2009) (i.e. correlation of the scoring performance of a team with itself across the game). and (ii) for each pair of opposing teams by computing the cross-correlation function (CCF) as measure of cross-similarity, which refers to the correlation between two time series as a function of the lag of one relative to the other (Horton, Srinivasan, and D'Zmura, 2014) (i.e., correlation between the scoring processes of the two opposing teams across the game). The ACF was computed with a lag length of three time intervals (i.e. 30 seconds), allowing the examination of the correlation in approximately each ball possession (i.e. teams must attempt a shot for a field goal within 24 seconds). The CCF was computed in each of the 10-seconds intervals of the time series (i.e. lag=0, no time-offset). Positive ACF and/or CCF values indicate persistence and/or correlation in the scoring performance of the team/s. The higher the ACF and/or CCF values the greater the persistence and/or correlation.

In a second step, the degree of synchronisation between the scoring processes of each pair of opposing teams was examined. This was accomplished by computing the Hilbert transform, which allows quantifying the phase relationship between two time series (i.e. in-phase or anti-phase behaviours) as a means to uncover the dynamics of synchronisations and coordination between the signals (Rosenblum and Kurths, 1988). Prior to these calculations and for the purpose of smoothing out short-term fluctuations in the data, the double backward moving averages on the time series were computed (Jönsson and Eklundh, 2004). It was decided to consider

a period of three units (i.e. length=3) when calculating moving averages in order to depict the momentary strength of the teams (i.e. approximately one ball possession) and the interaction between their scoring processes. This consecutive calculation of moving averages made the first 40 seconds of the game fall outside the computation domain, which merely represents 1.67% of the total game time. As previously explained, these double backward moving average data were subjected to relative phase analysis using the Hilbert transform. With the aim of facilitating the interpretation of the relative phase values returned by the Hilbert transform, these were shifted to the range (-180°, 180°). These normalised relative phase values must be interpreted as follows: 0° represents in-phase behaviour (synchronous pattern of coordination), -180° and 180° represent anti-phase behaviour (asynchronous pattern of coordination), and intermediate values represent coordination behaviours between in-phase and anti-phase depending on their proximity to these ranges.

In the particular case of the time series representing the scoring processes of each pair of opposing teams in basketball close games, and following the criteria established in previous research (Prieto *et al.*, 2015), relative phase values in the range -10° to 10° were considered to represent periods of strong coordination in the scoring process of the two opposing teams (i.e. similar scoring streaks by the two teams).

Whereas relative phase values out this range were considered to represent periods of low or no coordination in the scoring performance of the teams (i.e. scoring streak for one of the teams). The farther away from the range -10° to 10°, the lower the scoring coordination between the teams (i.e. game periods in which one team's scoring performance is very successful whilst the other team's is not). A frequency histogram distributed into 10° range bins was generated on the basis of the calculated relative phase values to allow a visual interpretation of the results. In a final step, the scoring performance variability of the teams throughout the game was assessed by the standard deviation (*SD*) of the mean relative phase values as a measure of the deviation from the central tendency.

Throughout all these calculations, the potential differences in the game-scoring coordination patterns of the teams across the games were assessed controlling for the game period. To this effect and based on the division of the playing time into four 10-minute game quarters established by the international governing body for basketball (FIBA) in the analysed competitions, the following game periods were considered: first quarter, 0-10min; second quarter, 10-20min; third quarter, 20-30min; fourth quarter, 30-40min; extra time (if necessary), 40-45min.

Statistical analysis

Descriptive data were computed to describe the teams' scoring performance on the basis of the relative phase calculated values (frequencies of occurrence, mean values and standard deviations). One-way analyses of variance were performed to test for differences in the teams' scoring performance depending on the game period. Tukey's post hoc multiple comparisons when significant effects were found. Effect sizes (*ES*) were calculated using the partial eta squared (η^2_p) and their interpretation was based on the following criteria: $0.01 \leq ES < 0.06$ small effects, $0.06 \leq ES < 0.14$ moderate effects, $ES \geq 0.14$ large effects (Cohen, 1988). The significance level was set to $P \leq 0.05$. Statistical analyses were performed using SPSS 21.0 software (IBM Corp., Armonk, NY, USA). Matlab R2016a mathematical software (The

MathWorks Inc., Natick, MA, USA) was used for calculating Hilbert transforms.

Results

Table 1 shows the ACF and CCF values (mean ± SD) for all the analysed games. The ACF results showed a very strong scoring persistence for each of the teams across the games, with positive values close to 1 (i.e. almost a perfect correlation) for winners and losers. Similarly, the CCF results showed very positive values close to 1 (i.e. almost a perfect fit between the time series representing the opposing teams' scoring performance).

Figure 1 shows the frequency histogram of the relative phase values for all the analysed games. 89.16% of these values (n=2,525) fell in the range -10° to 10°, revealing periods of strong coordination in the scoring process of the teams along the games. The remaining 10.84% (n=307) ranged on the spectrum of relative phase values above 10° or below -10°, revealing periods of low or no coordination in the scoring processes of the teams.

Figure 2 shows the relative phase values (mean ± SD) for all the analysed games according to the game period. This chart should be interpreted together with Table 2, which presents the frequencies of occurrence of these relative phase values within or outside the range representing strong scoring coordination processes between the teams (i.e. ranging from -10° to 10°). The results reveal patterns of a lower coordination in the scoring processes of the teams during the first two quarters of the game (73.81% and 82.22%, of the relative phase values within the range -10° to 10° respectively), which become extremely high coordinated in the second half of the game (3rd and 4th game quarters; 99.58% and 100.00% of the relative phase values ranging from -10° to 10° respectively) and in the overtime (if played; 100% of the relative phase values in the range -10° to 10°).

The subsequent analysis of variance (one-way ANOVA) showed large significant effects depending on the game period ($F_{3,44} = 8.246, P < 0.001; ES = 0.360$) Post-hoc Tukey's multiple comparisons confirmed a significant lower game-scoring coordination for the 1st and 2nd game quarters compared to 3rd and 4th game quarters, as well as to extra time (if played) (see Table 3 for statistical significance and confidence intervals). That is, the progression of the game in each of its halves leads to a higher coordination in the scoring performance of the teams. This pattern of coordination is also revealed when the relative phase standard deviation values are plotted (Figure 3).

Discussion

Time series analysis methods were used to study the scoring coordination patterns in final round close games of men's professional basketball International Championships of National Teams. The results of the initial autocorrelation and cross-correlation functions analysis, together with the relative phase frequency histogram, showed a high consistency in the scoring processes of the two opposing teams in all the games. This is consistent with previous research in different team sports when focusing on close games (e.g. Prieto, Gómez and Sampaio, 2015 in handball), including basketball (DeSáa et al., 2012; García et al., 2015; Sampaio, Lago, Casais and Leite, 2010). In this regard, the fact that the sample was composed by very balanced games (i.e. close games) suggests that the potential initial differences in the level of the teams are minimised and that they perform at a very similar level (i.e. tight score difference). One particular fact that could show a more marked effect in the sample of the present study: final round games, as these games are usually played, at least theoretically, by the top-level teams of the competition and promise, yet again theoretically, very tight games.

ACF		CCF
Winner	Loser	
0.9728 ± 0.0044	0.9736 ± 0.0040	0.9822 ± 0.0153

Table 1. Values of the ACF and CCF for all the analysed games (mean ± SD).

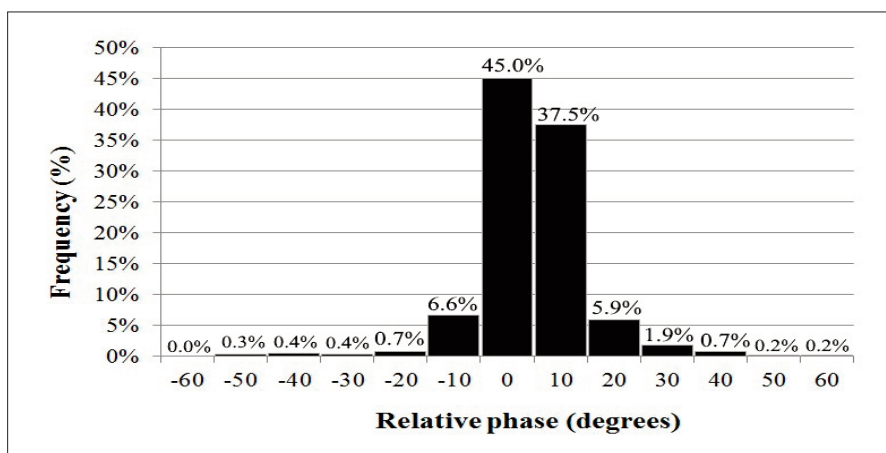


Figure 1. Relative phase frequency histogram. Discontinuous vertical lines delimit the relative phase values representing periods of strong scoring coordination between the teams (ranging from -10° to 10°).

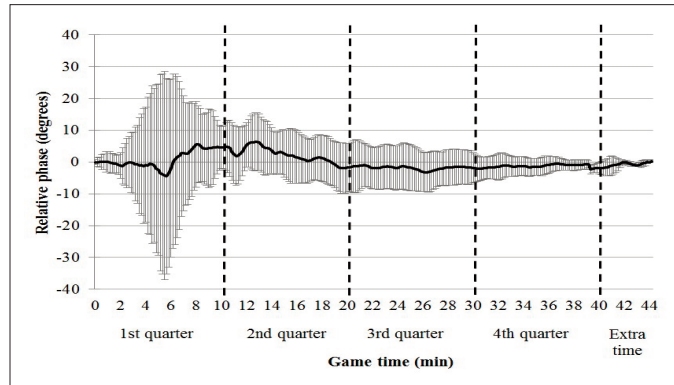


Figure 2. Relative phase scoring ratings for all the analysed games (mean ± SD). Black longitudinal line represents mean relative phase values. Grey vertical lines represent standard deviations. Discontinuous vertical lines represent game quarters.

Game period									
First quarter 0-10min		Second quarter 10-20min		Third quarter 20-30min		Fourth quarter 30-40min		Extra time 40-45min	
SCSP	LCSP	SCSP	LCSP	SCSP	LCSP	SCSP	LCSP	SCSP	LCSP
73.81	26.19	82.22	17.78	99.58	0.42	100.00	0.00	100.00	0.00

SCSP: Strong coordination in the scoring process; LCSP: Low or no coordination in the scoring process.

Table 2. Relative phase frequencies (%) according to the game period.

Multiple comparisons						
A	Game quarter B	Mean difference (A-B)	Sig.	95% Confidence interval		
				Lower bound	Upper bound	
1 st	2 nd	-8.41	0.561	-25.55	8.73	
	3 rd	-25.77	0.001 [†]	-42.91	-8.63	
	4 th	-26.19	0.001 [†]	-43.33	-9.05	
2 nd	1 st	8.41	0.561	-8.73	25.55	
	3 rd	-17.36	0.046*	-34.50	-0.22	
	4 th	-17.78	0.039*	-34.92	-0.64	
3 rd	1 st	25.77	0.001 [†]	8.63	42.91	
	2 nd	17.36	0.046*	0.22	34.50	
	4 th	-0.42	1.000	-17.55	16.72	
4 th	1 st	26.19	0.001 [†]	9.05	43.33	
	2 nd	17.78	0.039*	0.64	34.93	
	3 rd	0.42	1.000	-16.72	17.55	

Significance: * $P \leq 0.05$; [†] $P \leq 0.001$

Table 3. Relative phase frequencies post hoc comparisons according to the game period.

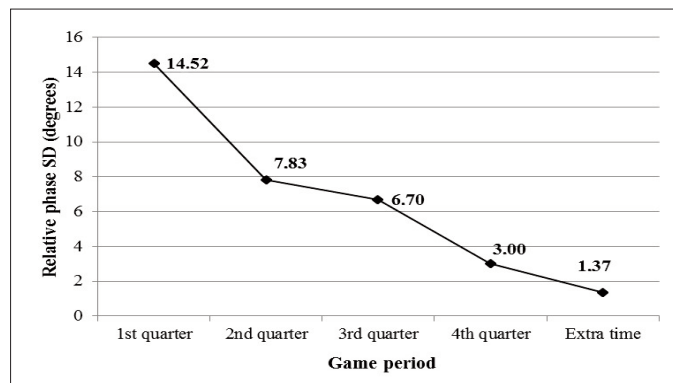


Figure 2. Relative phase scoring ratings for all the analysed games (mean ± SD). Black longitudinal line represents mean relative phase values. Grey vertical lines represent standard deviations. Discontinuous vertical lines represent game quarters.

When delving into the relative phase analysis according to the game period, the results revealed an increasing scoring coordination pattern between the teams as the games unfolded, showing extremely high coordinated behaviours in the 3rd and 4th quarters (i.e. similar scoring streaks by the two teams; back-and-forth scoring patterns). This suggests that are the first two quarters of the games (first half; 0-20min) those leading to major fluctuations on the scoreboard (i.e. game periods in which one team's scoring performance is very successful whilst the other team's is not). Thus, the first two quarters result in greater differences in the score that are stabilised as the game progresses throughout the final two quarters of the game. In other words, the results suggest that are the first two quarters those that allow the teams to break the games and that during the second half of the game (3rd and 4th quarters) is difficult to establish major differences on the scoreboard, which evolve in a highly synchronized way. These observed scoring coordination patterns between the teams are consistent with recent studies following this methodology in basketball and handball leagues (García et al., 2015; Prieto et al., 2015, respectively) and highlight the importance of the initial phases of the game in basketball teams' performance (Sampaio et al., 2010; Sampaio, Lago and Drinkwater, 2010). In this regard, the consideration of team sports as complex adaptive systems within the framework of ecological dynamics may contribute to explaining the observed increasing game-scoring coordination. This scoring coordination is manifested in a continuous and gradual process of familiarisation and co-adaptation between teams (and players) that result in more predictable collective behaviours as the game progresses and, therefore, in more stable scoring dynamics between the teams (i.e. back-and-forth scoring) (see Davids, 2015 for a review on team sports complex adaptive systems).

Psychological factors may also contribute to explaining the results of the study. In this regard, the relationship between athlete's psychological state and performance in sporting competitions constitutes an important topic of study in the field of sport psychology (Weinberg and Gould, 2003). In particular, the arousal-performance relationship has been widely used in order to assess athletic performance (Wrisberg, 1994). Bar-Eli and Tenenbaum (1989a) proposed a model of psychological performance crisis in sports competitions that highlights the frequent states of psychological stress experienced by players, which may raise their

arousal levels affecting performance. Overall, published studies report deterioration in athlete's performance when reaching extreme levels of arousal that might result in a state of 'psychological performance crisis' (Bar-Eli, Tenenbaum, and Elbaz, 1990). In the particular case of basketball as a high-scoring sport, the continuous changes in the score and the low game-scoring coordination between the teams (as found in the first two quarters of the games) may result in operationalise feedback effects in terms of game standings subjectively perceived by the player that can lead to positive, negative or uncertainty-arousing tendencies affecting concentration and performance (Bar-Eli and Tenenbaum, 1989b; Raviv and Nabel, 1988).

From a practical perspective, basketball National Team coaches should specifically design practice tasks simulating the different competitive environments that can occur within the initial two quarters of the game (i.e. lower game-scoring coordination between the teams; big differences in the score either winning or losing). Furthermore, training aspects (physical, technical, tactical, psychological) should focus on creating practice tasks geared towards the successful regulation of the individual and collective behaviours of players when the score is tight, especially considering the added pressure when playing in these conditions because of the higher impact of decisions made and actions performed by the players. The objective is to create representative practice tasks containing informational constraints with the aim of developing control strategies, special tactics and specific plays to achieve the highest control of the game (Araújo, Davids and Passos, 2007; Fajen, Riley and Turvey, 2009).

Conclusions

In summary, the results of the present study revealed an increasing scoring coordination pattern between the teams as the games unfolded, showing extremely high coordinated behaviours in the 3rd and 4th quarters (i.e. similar scoring streaks by the two teams; back-and-forth scoring patterns). This suggests that are the first two quarters of the games those leading to major fluctuations on the scoreboard (i.e. game periods in which one team's scoring performance is very successful whilst the other team's is not). This study may be matter of interest to coaches and performance analysts in the field of basketball, providing practical information for specific games preparations in International Championships of National Teams.

PATRONES DE COORDINACIÓN ANOTADORA EN LOS CAMPEONATOS INTERNACIONALES DE BALONCESTO DE SELECCIONES NACIONALES

PALABRAS CLAVE: series temporales, sistemas dinámicos, sistemas complejos, fase relativa, transformada de Hilbert

RESUMEN: El rendimiento de dos equipos de baloncesto se puede analizar mediante la exploración de sus diferentes dinámicas de anotación sobre la base de las dos series temporales que representan el proceso anotador de cada equipo durante todo el partido. Los estudios existentes siguiendo este enfoque se han centrado principalmente en partidos de temporada regular y de playoff en diferentes ligas de baloncesto. El objetivo de este estudio fue llevar a cabo este tipo de análisis en partidos de campeonatos de selecciones nacionales, centrándose específicamente en los partidos ajustados de las rondas finales, como aquellos en los que se deciden las medallas y en los que los equipos desempeñan en un nivel muy similar. El estudio considera los partidos de las rondas finales (semifinales, tercer y cuarto puesto, y final) de los principales campeonatos internacionales de baloncesto de selecciones nacionales en categoría masculina (Campeonatos Europeos, Campeonatos del Mundo y Juegos Olímpicos) disputados durante el período 2005-2013. Se

utilizaron diferentes métodos de análisis de series temporales (funciones de autocorrelación y correlación cruzada, doble media móvil, transformada de Hilbert). Los resultados revelaron un patrón creciente de coordinación anotadora entre los equipos a medida que los partidos avanzaban, mostrando patrones de coordinación extremadamente altos en el tercer y último cuarto (rachas de anotación similares para los dos equipos, patrones de anotación de ida y vuelta). Esto sugiere que son los dos primeros cuartos de los partidos aquellos que conducen a mayores fluctuaciones en el marcador (períodos de juego en los que el rendimiento anotador de un equipo es muy exitoso, mientras que el del otro equipo no lo es). Este estudio puede ser de interés para los entrenadores y analistas de rendimiento en baloncesto, proporcionando información práctica para la preparación específica de partidos en los campeonatos internacionales de selecciones nacionales.

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