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How the "rapport de forces" evolves in a soccer match: the dynamics of collective decisions in a complex system

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HOW THE "RAPPORT DE FORCES" EVOLVES IN A SOCCER MATCH: THE DYNAMICS OF COLLECTIVE DECISIONS IN A COMPLEX SYSTEM

KEYWORDS: Soccer, Complex system, Modeling, Tactics, Moves.

ABSTRACT: This article discusses the contribution of dynamics to the study of complex systems with regards to performance analysis in soccer. Evaluation tools are presented to better understand how the "rapport de forces" evolves with perturbations of play, contraction / expansion phases of game play, and possession of the ball. It is hypothesized that application of these tools and models may enable researchers and trainers to efficiently analyze configurations of play and identify those that appear to be critical for success. All things considered, nothing may be fundamentally understood about team sports if one does not shift from a spatial to temporal reference system. It makes it possible to bring to light the system's evolving trends. This way, it is possible to understand how players produce functional behaviors or answers to momentary configurations of play, whatever their complexity.

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— *Artículo invitado con revisión*

Complex systems analysis is a scientific field which studies the common properties of systems considered complex in nature, society and science. The key problems of such systems are difficulties with their formal modeling and simulation. From such perspective, complex systems are defined on the basis of their different attributes. The study of complex systems brings new vitality to many areas of science where a more typical reductionist approach has fallen short. Complex systems analysis is therefore often used as a broad term encompassing a research approach to problems in many diverse areas such as team ball sports. From a systemic analysis point of view, key concepts, such as self-organization, time and constraints, can be used to help explaining stability, variability and transitions among configurations of play (Gréhaigne, 1989).

The central notion of opposition leads us to consider the two teams involved in a match as interacting organized systems. A systemic view of team sports may then be seen as fundamental to the emergence of a new understanding of the game. In a more commonly (and traditionally) used learning approach, one tries first to teach students the technical skills of the game and second to maintain order on the playing field, by the use of formal groupings, for instance (Garganta, 1997; Gréhaigne, 1992).

We are tempted to say that it is as important, and maybe more important, to get players to optimally manage disorder (Gréhaigne, 1989; Gréhaigne y Godbout, 1995; Villepreux, 1987). A game rarely rests upon the simple application of tactical combinations learned previously during training. Thus, most of the time during the game, one can foresee

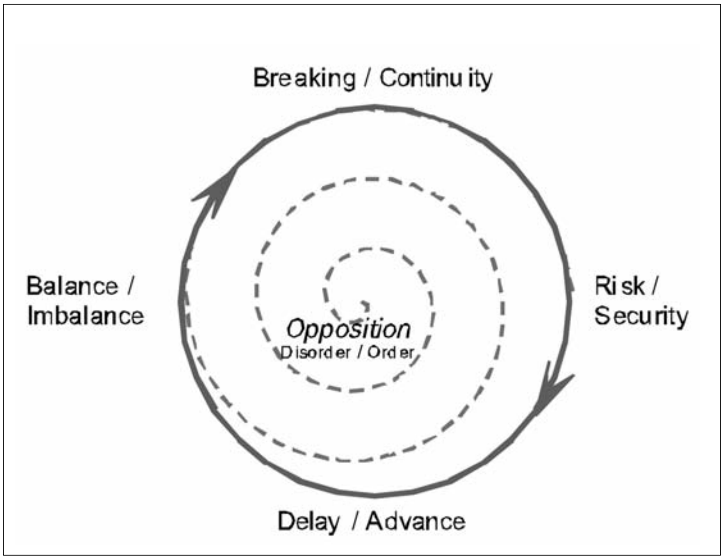

Figure 1. Concepts related to the notion of opposition (Translation from Gréhaigne, 1992).

only probabilities of evolution for the attack and defense configurations, hence the importance of player's tactical knowledge to rapidly and efficiently solve game play problems (Figure 1).

The concept of opposition, between two teams, helps in highlighting the notion of pressure on a particular point in the game play, in order to break the balance of forces in momentary configurations of play. Such a pressure creates a favorable imbalance in order to score a goal. Finally, two aspects are contradictory to manage in the attack:

Taking risks in order to create an advantage (thus creating an imbalance in the opponents), but at the expense of maintaining an adequate defensive coverage;

Putting emphasis on security, temporarily preserving some stability in the exchange of ball, but without really putting the opponent in trouble.

From the defense point of view, players may favor security by maintaining temporarily one's defensive stability (in order to avoid being late or in pursuit), but in so doing, the initiative of the game is left to the opponents.

Moreover, the temporal dimension is important in studying these systems because it is the medium through which they operate and evolve (Davis and Broadhead, 2007). One of the most important performance parameters is the speed of the play (Gréhaigne, 2009). All things considered, nothing may be fundamentally understood about team sports if one does not shift from a spatial to a temporal reference system. The synchronous properties of a system relate to the relationships between several of its characteristics at a given time. The diachronic properties relate to the relationships of those same characteristics through many successive moments in time. They make it possible to bring to light the system's evolutionary trends.

Team ball sports in general, and soccer in particular, can be considered as complex systems composed of many interacting components (Araújo, Davids, Bennett, Button y Chapman, 2004; Gréhaigne, 1989; Gréhaigne, Bouthier and David, 1997; McGarry, Anderson, Wallace, Hughes and Franks, 2002). The theory of open complex systems seeks to explain how regularity emerges within a given system. This implies the consideration of the concept of equilibrium / non-equilibrium phase transitions in the study of systems and models (Walliser, 1977).

For us, the heart of this theory is how configurations of play are formed and transformed as complex systems with small changes in the opposition relationship. From this viewpoint, game play can be characterized by order-disorder transitions (Gréhaigne, 1989), where individual or collective actions may destabilize or (re)stabilize the system of play. These ideas fit well with tactical considerations in team sports since, at one level of analysis, the game can be described as a series of subphases. For instance, at the "match" organizational level, the set made of the confrontation of two teams, has structural and functional characteristics. By structural, one means the spatial organization of the constituent elements of the system, while the functional aspect refers to the various time related processes such as exchanges, regulations and re-organization of the elements. Functionally-wise, one is dealing with the evolution in time of the opposing relationship between the two teams (advance, delay; breaking, continuity). These opposition settings that momentarily involve some of the players generate a particular shape of play representing the "partial forefront organizational level". At any specific moment, according to the evolution of play, this reciprocity relationship offers, for example, a specific problem to attackers but, at the same time, contains pertinent solutions for conducting the action (Gréhaigne, 1992).

Gréhaigne et al. (1997) argued that changes in the momentary configuration of game play have to be examined in light of the previous configurations, an example of the concept of conditional coupling in complex systems theory (Davids, Araújo and Shuttleworth, 2005; Davids, Button and Bennett, 2008). They concluded that "choices are made based on position, movement and the speed of one's teammates and opponents" (p. 148). With the opposition relationship, order and disorder can emerge from the play at any moment. "This way, the energy and choices of the players serve to create the conditions for transitions between configurations of play and transform the play" (p. 148). These transitions may best be understood in terms of the interactions of multiple local factors (location of the players and of the ball, their speed, player's cognitions and resources, etc.).

Next, we discuss the use of complex systems theory with regards to performance analysis, using football for illustrations. Evaluation tools are presented to better understand how the "rapport de forces" (Gréhaigne, Godbout y Bouthier, 1999) evolves with perturbations of play, contraction / expansion phases of game play, and possession of the ball. It is hypothesized that application of these tools and models may enable researchers to efficiently analyze configurations of play and identify those that appear to be critical for success.

Adopting a vocabulary focused on dynamics implies a clear understanding of the terms used. We shall therefore consider, in this paper, the different terms used when one wants to talk about location and displacement. To this end, we tested the concepts of effective play-spaces in expansion and / or contraction to experiment different analysis of the "rapport de forces" between two teams. Transitions and transition game play often refer to configurations where one has sufficient time to act because the density of the players is less important: the attack must stay ahead of the effective play-space and the defense must go back or stay in block. The use of long-ball plays changes rapidly configurations. Once players perform the long-ball play the configurations change shape and are most often in expansion. For its part, the "in compression" model appears in a stabilized game play with a high density of players.

This succession of momentary configurations of play between regaining possession of the ball and the loss of the ball is a sequence of play. Main actions on the circulation of the ball and players may be categorized as follows:

– Ball stopped in the contraction;
– Ball stopped at the periphery of the contraction;
– Moving ball towards the contraction;
– Ball stopped in an expansion phase;
– Ball moving in an expansion phase;
– Moving the ball at the periphery of either the contraction or the expansion.

One must, of course, consider both the paths and trajectories of the ball in order to obtain a more accurate assessment of the situation and a better idea of the "rapport de forces" between attack and defense.

Observation of game-play

To better understand the contribution of a complex system approach to the conception of team-sport learning, we use the notion of effective (occupied) play-space (EP-S) as a tool to extract data on the evolution of game-play.

Effective play-space

If one considers a given configuration of play (see Figure 1), one can summarize it using the notion of effective play-space, as illustrated in Figure 2 (Gréhaigne, 1989; Gréhaigne, Richard and Griffin, 2005; Mérand, 1977). The effective play-space (EP-S) may be defined as the polygonal area that one obtains by drawing a line that links all involved players located at the periphery of the play at a given instant.

This conception of effective play-space postulates that between the elements of both teams in competitive opposition settings, a structuring of cooperation and opposition relationship takes place. Considering the location of the EP-S on the field and the direction of the attack, the position of players of both teams and the position of the ball constitute a particular configuration of play at instant T. In these conditions, the defined shape of a particular configuration and its possible evolution may provide significant information on the value and the limits of a player’s adaptation, that is to say on what his/her behavior expresses in terms of innovation, invention, or unlikely “regression” when confronted to opponents.

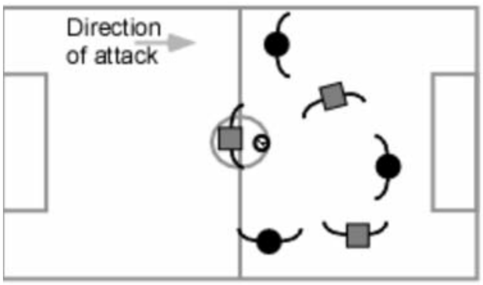

Figure 2. A given configuration of play in soccer. The ball is at the rear of the configuration.

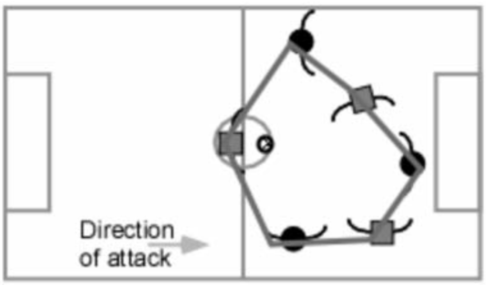

Figure 3. The effective play-space (EP-S) of this configuration.

Offensive and defensive effective play-spaces (OEP-S and DEP-S)

Considering the respective positioning of attackers and defenders, one may also determine an offensive effective play-space (OEP-S) and a defensive effective play-space (DEP-S). Then, two more or less interpenetrated polygonal surfaces are obtained (see Figures 4 and 5 where polygonal areas are schematized in triangular form). The relationship between these two opposing areas and their respective evolutions in time may enlighten us on changes in the balance of the opposition relationship during matches. Particularly, the location of the ball or of the ball holder in the offensive effective play-space, according to the attack phases, provides good indications depending if the ball is at the rear, within, at the periphery or at the front of the offensive effective play-space.

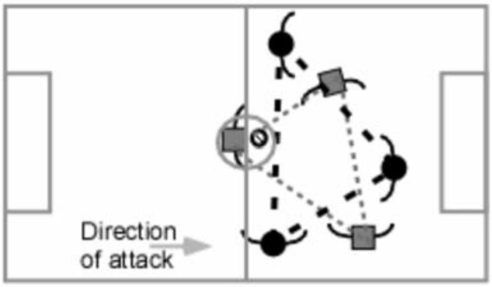

Figure 4. OEP-S and DEP-S.

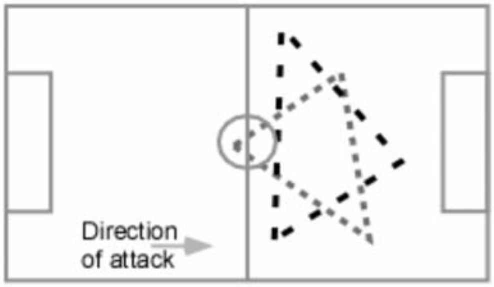

Figure 5. Modeling of OEP-S and DEP-S.

Modeling of OEP-S and DEP-S

A given cloud of points, as in a configuration of play, can be characterized by its "center of gravity" and its two principal axes (Gréhaigne, 1989). This type of analysis is particularly useful in research because the reciprocal positions of the centers of gravity appear to constitute an important indication in characterizing the notion of "in block" (Figure 6) or "in pursuit" for the defense (Figure 7). We shall consider that the defense is in "block" when it is generally positioned between the ball holder, the attackers and its own goal. We shall consider that the defense is in "pursuit" when it is generally positioned behind the ball holder, the attackers and its goal (Gréhaigne, 1990).

A defense in pursuit is a defense momentarily out-of-position which seeks to reposition itself as quickly as possible between the ball and goal; in this case the attack is in advance on the defensive replacement (Caty, Meunier and Gréhaigne, 2007).

So, we can sum up the dimensions and the surface of a cloud of points representing the attack or the defense. The main dimensions can be studied according to their

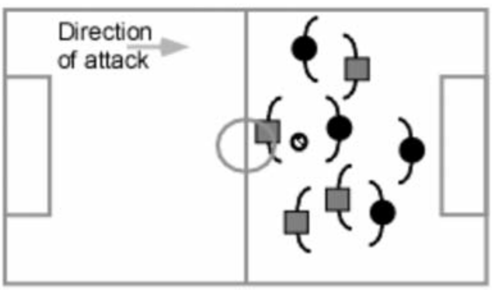

Figure 6. Defense (black circles) in block and ball at the rear of the EP-S for the grey squares.

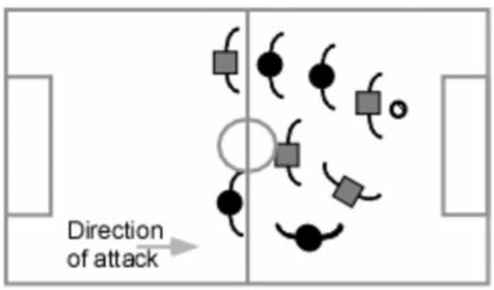

Figure 7. Defense (black circles) in pursuit and ball at the front of the EP-S for the grey squares.

length or their width and their prevalent direction in relation to the dimensions of the field, meaning its width or its depth. In our example (Figure 8), we studied different shapes of EP-S based on this idea.

A preliminary analysis of the different positions and shapes of the effective play-spaces led us to suggest a theoretical typology of the configurations that can be obtained when defense is in block. We shall call:

A1: an attack configuration where the main dimension of OEP-S is widthwise. The same shape for the defense will be called D1;

A2: an attack configuration where the length of OEP-S is nearly equal to its width. The same shape for the defense will be called D2;

A3: an attack configuration where the main dimension of OEP-S is lengthwise. The same shape for the defense will be called D3.

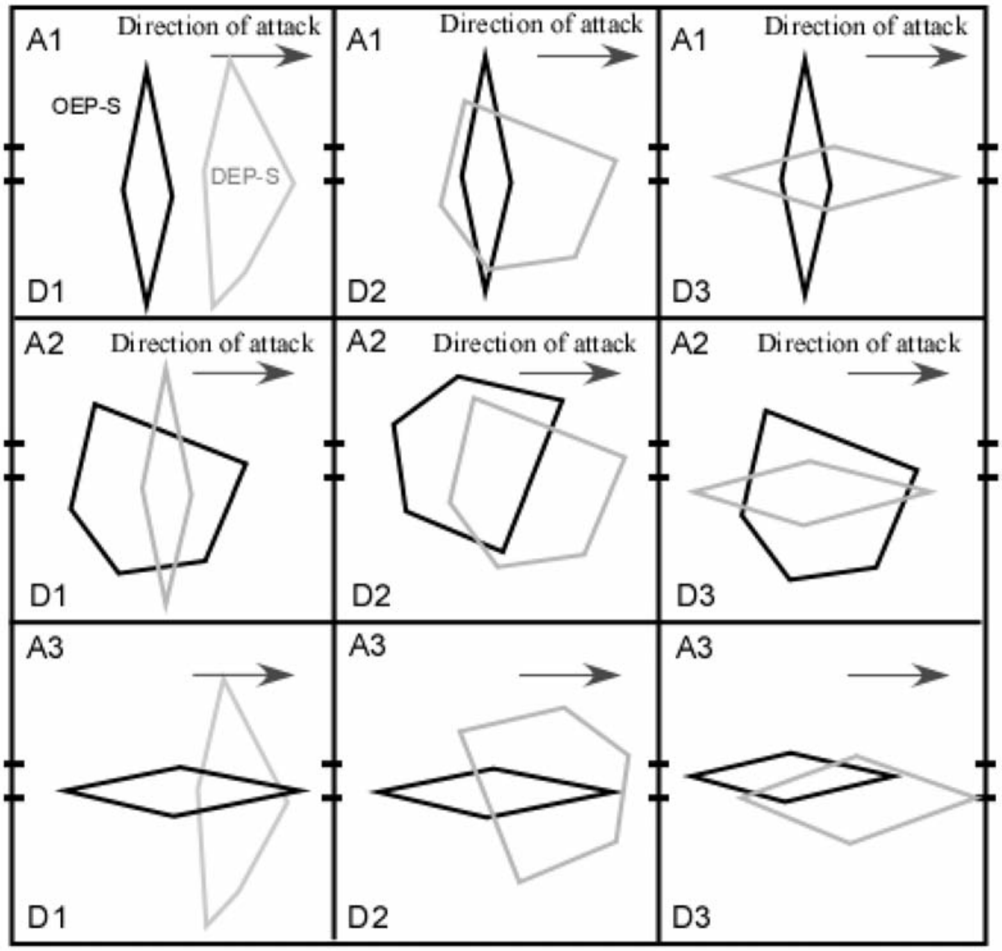

Figure 8. Modeling of OEP-S (grey) and DEP-S (black) with defense in block.

From a formal point of view, if we combine these different configurations one by one we obtain a theoretical matrix of nine possible cases. If the defense is not in block, there are other reciprocal rapports between the two EP-Ss. For an inventory of these different configurations, see Gréhaigne, Caty and Marle (2004, 2007). For ball moves in relation to effective play-space, see Gréhaigne et al. (2005).

Location of EP-S

One other important information relates to the location of the EP-S on the field. To insure reliable observations, data are based on two criteria (see Figure 8):

– Location of ball recovery with reference to the field: high-ball recovery (in the opponents' side of the field); recovery in the middle area of the field; low recovery (in one's own side of the field); recovery at the periphery.

– Location of recovery with reference to the effective (occupied) play-space (EP-S): recovery at the front of the E P-S; recovery at the rear or the middle area of the E P-S.

Figure 9 illustrates different effective play-spaces (high, middle and low); areas of ball recovery are analyzed with respect to “defense in block” plays or “in pursuit” plays, with the ball at the rear or at the front of EP-S.

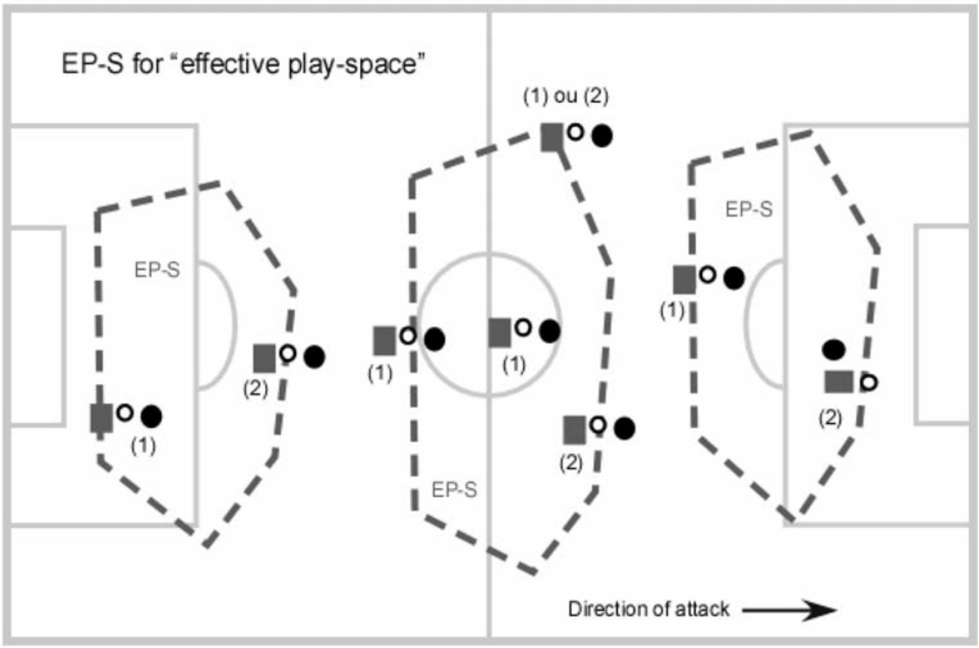

Figure 9. Different areas of ball recovery analyzed with respect to “defense in block” plays (1) or “in pursuit” plays (2).

Complexion of play

During a match, a unit of play evolves from a state 1 to a state 2 and so on to a state n. As in a photo, the configuration of play is defined by the position of all players at a moment *M*. Through the analysis of the different ball-holders' tactical choices prior to a goal, one may better understand how goals are scored. To that end, Gréhaigne et al. (1997) have devised some diagrams representing the few seconds preceding a goal. For each player, one can note a) the player's position, b) the direction of his/her movement and c) the speed of his/her movement. These parameters define the potential turning angle and the amount of ground that can be covered. To represent those kinetic data on a plane, we have proposed (Gréhaigne et al., 1997) the notion of "sector of play" for the attackers and that of "sector of intervention" for the defenders. Those sectors spatially define the limits of possible actions for the different players, within one second, considering the three parameters mentioned above. With reference to concepts used by Plank (1941) in physics, we shall name such a distribution a "complexion of system". In short, the purpose is to describe the "dynamic states" of players who participate in the attack and those of their opponents. Whereas a static configuration of play is illustrated in Figure 10, dynamic pictures of the transition between two configurations of play are illustrated in Figures 11 (between moment 0 and moment 1, one second) and in Figure 12 (between moment 0 and moment 2, two seconds).

Despite an apparent disorder suggested by the simple static spatial distribution of the players on the field or court, a dynamic analysis of the play actually indicates a more general homogeneity with respect to players' moves. Whereas the static spatial distribution of players (Figure 10) suggests several possible tactical decisions on the part of the attackers (grey circles), the two successive

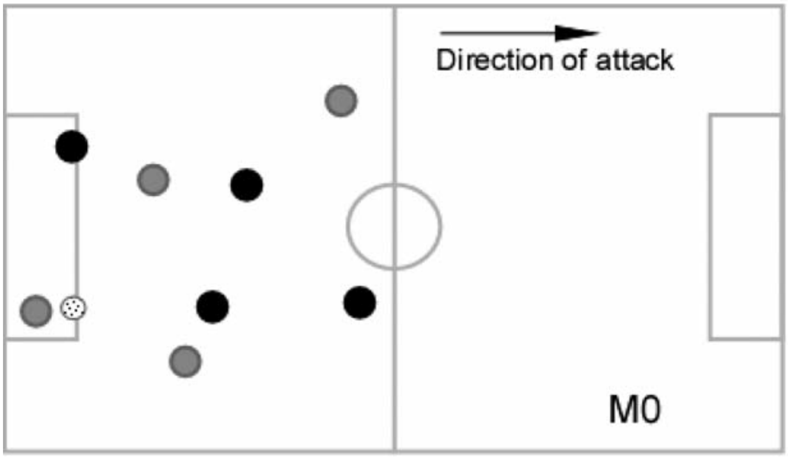

Figure 10. Static spatial distribution at M 0.

dynamic configurations of play (Figures 11 and 12) suggest a relatively balanced confrontation between attackers and defenders.

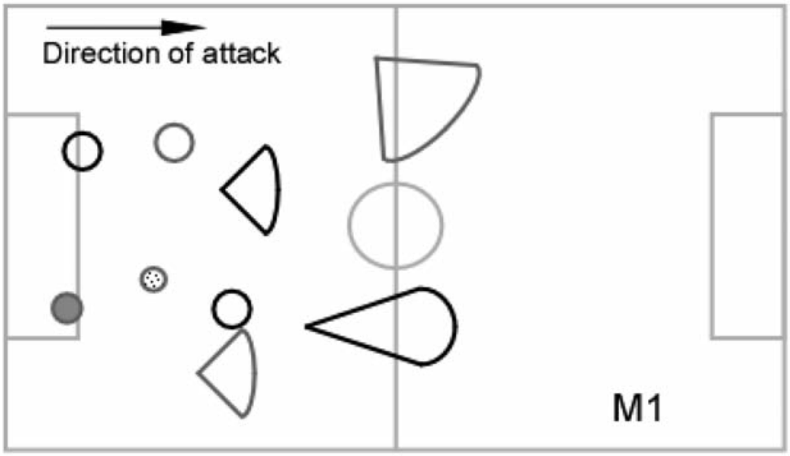

Figure 11. Dynamic configuration of play at M1 (sectors of play in gray and sectors of intervention in black).

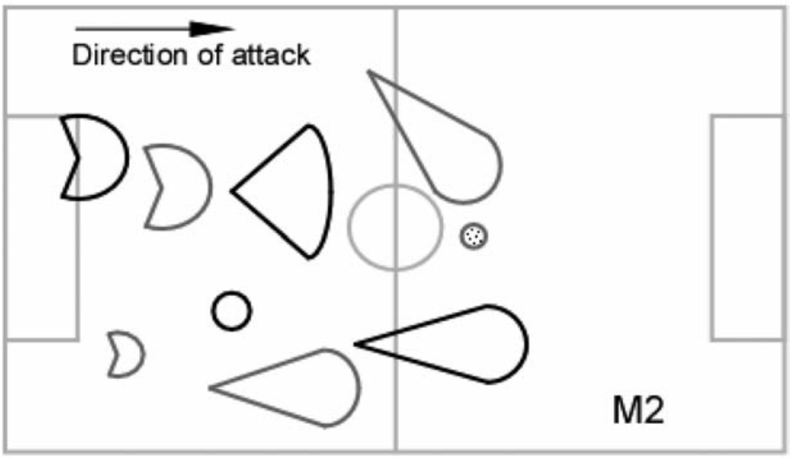

Figure 12. Dynamic configuration of play at M2 (sectors of play in gray and sectors of intervention in black).

In a complex system like a soccer match, all players affect each other in an intricate way. Focusing on each player individually disrupts the observer's perception of players' usual interactions. It is, therefore, inappropriate to study a configuration of play apart from its environment, the match system (Gréhaigne and Godbout, 1995).

Part of the receivers' sectors of play (Gréhaigne et al., 1997) is always free in order for them to exchange the ball or to shoot on goal according to their position. When a team is attacking, the idea is to create or keep available time and, consequently, available space. The ball should be passed to the player who is in the best position to penetrate defense: that player is not necessarily the one with the largest space available.

Such results show that the receivers' positions and their way of moving are important information for the ball holder. Concepts of sector of play and sector of intervention can be used to provide information both for attack and defense.

Observation and system

The stable state of a system is the one for which chances of occurrence are the greatest. In other words, it is the one that can be reached or realized in most different ways. In fact, this definition of stability depends on the observer's intention.

Observation and intention

To be more precise, let us consider two different observers of a system composed of 'n' players on the field. A first observer considers each of the 'n' players as distinct individuals, whereas the second one considers the elements as equivalent to a dynamic configuration of play. The first observer is not interested by the "complexions", but by the "static repartition modes" of the players. Considering that the second observer can only take into consideration the different "complexions" of the system, it is obvious that the first observer has more work to do for describing the system (having more different states to consider).

The work of our second observer is even made easier due to the fact that for him or her, the different states of the system do not have the same probability of occurrence. He is able to define as a "stable dynamic state" the one where all players are distributed equally on the field. In this case, one accepts not to detail, not to differentiate; when one agrees to let the perception of details grow poorer, one improves his/her understanding of the whole system. However, the difference between the two observers is only due to the fact their observations do not have the same level of precision. Inherently, our two observers have done the same kind of work to characterize the elements, to "classify" them, but each using a different scale:

The first observer has characterized the 'n' players according to static criteria (one criterion being the fact that players are part of one of two sets, the two teams);

The second one had only to classify players depending upon their dynamic distribution on the field.

This passage from one level of analysis to the other has structured the observers' vision of the system and has provided a frame of reference, consciously or not. A match constitutes a complex system. On the field, a non-homogenous distribution of the players brings about a non-homogeneous distribution of their energy state. A certain kind of homogeneous scattering characterizes the equilibrium state toward which invasive team sport systems always evolve. It corresponds, therefore, to a homogeneous distribution of the players on the different energetic states.

The degree of homogeneity of the dynamic configurations of play can also be explained by a distribution of the probabilities of the presence of the players in certain parts of the field.

It means that those states would seem to be more homogeneous for an observer who would be able to recognize the different kinetic states, as is the case for the second observer. Conversely, a classic observation would stress the heterogeneous aspects by dealing only with positions and geometric shapes. That is how, we think, the dialectic balance / unbalance of game play operates. On the one hand, very stable structures make one think of a crystalline structure… defined as rigid and with few chances of evolution, as for example in set-plays. On the other hand, the dynamical configurations of play have within themselves a number of transformations limited according to the different possibilities of the continuous evolution of the game but nevertheless important if one chooses a break in modifying the movement in process.

An elastic system

Chow, Davids, Button, Shuttleworth, Renshaw and Araújo (2007) have explored the potential of a nonlinear pedagogical framework, based on dynamic systems theory, as a suitable explanation for tactical approach in team sports in physical education. Nonlinear pedagogy involves manipulating key task constraints on learners to facilitate the emergence of qualitative information on game-play, functional movement patterns and decision-making behaviors. So, to better understand the evolution of configurations of play, it is possible to study shapes and distortions of offensive effective play-spaces (OEP-S) and defensive effective play-spaces (DEP-S). The main distortions are the respective contractions or expansions of the offensive or defensive effective play-space. A contraction of game play illustrates the presence of several players on a small surface; for its part, an expansion represents the distribution of several players over a large area. For us, an elastic system is made of a series of contractions and expansions. For players, it is necessary to find the stable solution of the system within a few seconds while a tension is applied to the system. To understand how an elastic system works, one must first understand how configurations of play work. In soccer, the dimensions of the field limit the elasticity of the system, widthwise and lengthwise. When the system is in large expansion, there are considerable perturbations and vibrations, and players are in motion at different velocities. This could constitute a first approach of a definition of disorder in team sports.

On a quick restart of the game or on a ball recovery and swift counterattack by the grey team, the type of configuration schematized in Figure 13 is very common. If the ball holder is a good thrower, the OEP-S lengthens, with a very significant expansion while the DEP-S is still in contraction.

In team sports, the notion of density of the players' distribution would refer to a rather qualitative approach to the observation of game play, whereas the concentration / dispersion construct seems more related to a quantitative approach in terms of number of players. Notions of compression / extension for the movement and of contraction / expansion about successive static states (or discontinuous temporal aspects) appear to work in close harmony to describe and anticipate the moves in game play and make appropriate decisions. This could be a way to explain the organic links between the concepts of time and space. The notion of open space is a dynamic datum constantly changing; it is created or it disappears depending upon player's runs and moves. We can then define the existence and size of an open space from the time it takes for a given player to cover it (go through it) and this, at a given speed. This idea of distance to be covered and speed of the player are, in our view, key concepts.

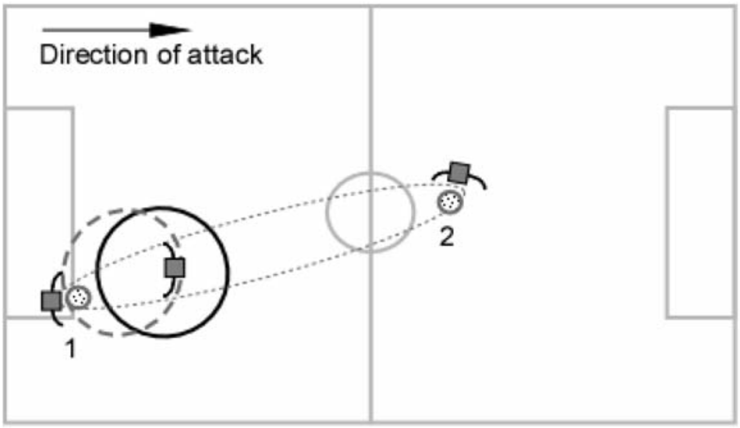

Figure 13. Contraction of the black / expansion of the grey within the elastic system.

During game play, the paths of the ball cause a succession of temporary contractions and expansions. Whenever the ball holder stops, the EP-S is reformed, often, in contraction in front of him/her and so on since every new pass induces changes in the configuration of game play.

With beginners (Gréhaigne et al., 2004), the succession of effective play-spaces are very reduced and concentrated. One can note that most often the ball circulates on the side or at the front of the EP-S following successive passes intended to go forward. The ball stops when it is thrown in the middle of the group of players. As is often the case, for a game level under ten hours of learning time, one can see, in this phase of ball circulation, a series of indirect plays with pauses that cause temporary contractions. At the end, if the ball reaches the key, one can observe a contraction game-play on a stable space (Figure 14, on the right hand side).

A succession of pauses by different ball holders often is the essential reason for this type of game-play. In that case, the EP-S usually reshapes itself in contraction in front of the player with the ball and so on. Now, let us consider another tool to analyze the opposition relationship.

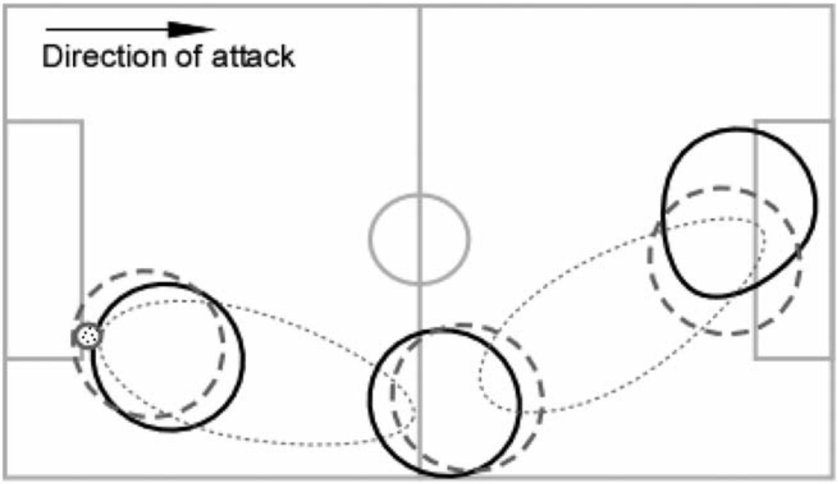

Figure 14. A succession of contraction / expansion.

Organizational level

Different organizational levels can be identified. In fact, during the game, the global opposition relationship that we call "match organizational level" breaks down into partial opposition relationships. These opposition settings that momentarily involve some of the players generate a particular shape of play representing the "partial forefront organizational level" (see Figure 15). At any moment of the match, this partial forefront contains a 3rd-level opposition unit that links the ball holder and his / her direct opponent. This is called "primary organi - zational level".

Figure 15 illustrates these organizational levels, whereas the drawing of the field would represent the "organizational level match". Thus the "rapport de force" (Gréhaigne et al., 1999) may be looked at as involving two teams, two sub-groups of players, or eventually two specific players. The continuity of opposition influences the opponents' moves not only at the one-to-one level, but at the partial forefront level and at the match level as well. These simultaneous interlocked opposition settings constitute the context of play (Bouthier, 1988; Deleplace, 1979). They evolve in reciprocal rapport in response to the evolution of any part of the system.

Towards a dynamic conceptual modeling of game play in soccer

We have seen in this paper that the configurations of play occur in varied parts of the field depending upon team strategies of offensive or defensive tactical decisions, the opposition relationship, the score at a given time, etc. Configurations of play may also be considered from a dual point of view, taking both attackers and defenders into consideration, either in the match system or in partial confrontation.

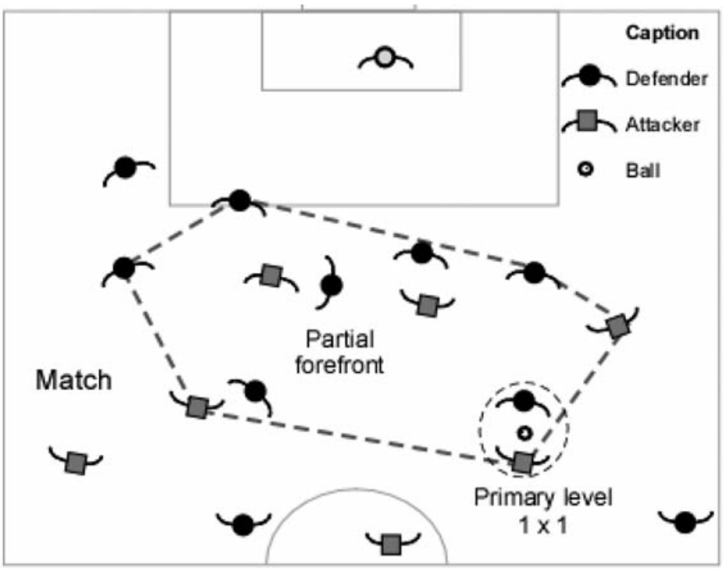

Figure 15. Match, partial forefront and primary organizational level.

The model presented in Figure 16 is an attempt to illustrate the use of complex system theory in team sports. In a closed space (the field or the court), four main evolutions of game-play (going forward, going backward, contraction and expansion of the effective play-space) are combined with paths and trajectories of the ball. One should note that this complex system operates in a closed space, the pitch or the court, which restricts the scope of expansion. Cooperation between offensive players is based on specific tactics intended to move the ball so as to bring it in the scoring zone and effectively score: penetrating, going around or over play. Cooperation between defensive players rests on two forms: man to man or zone defense. Defensive players may use one of two tactics: playing at the front of the ball or playing against the target line.

Some teams use forward defending, aggressively challenging the ball when on the defensive in any part of the field. Others rely on a “collapsing” style, that falls back deep into its own half when the opponent is in possession of the ball. The “forward” policy can put immense physical and psychological pressure on opponents. It has more physical demands however, and may spread a defensive formation more thinly. The “collapsing” approach is more economical in physical demand, and provides a packed back zone to thwart attacks. However it sometimes creates large gaps in midfield, and invites the opposing team to dribble forward and to take shots from long range; if the opposing team is good at the two aforementioned skills then goals will be conceded freely.

Moves, contractions and expansions of the effective (occupied) play-space are at the heart of our model. For the level "match system", each team is characterized by a level of disorder / order that shows the extent of organization or un-organization of the group of players. Perception of this level of disorder / order is useful to appreciate the collective functioning, but disorder must remain within an acceptable range to ensure the continuity of game play. Too much order in the attack leads to a simple and easy recovery tactical maneuver for the opponents. Too much disorder may induce confusion for the partners. Uncertainty is an important element strongly linked to time. A good information process and quick decision-making are key elements to reduce uncertainty. So, the objective for each team is to reduce uncertainty for itself and, at the same time, to increase uncertainty for the opposite team. The reality of evolving game play offers a very large variety of concrete game situations in connection with the notion of opposition relationship.

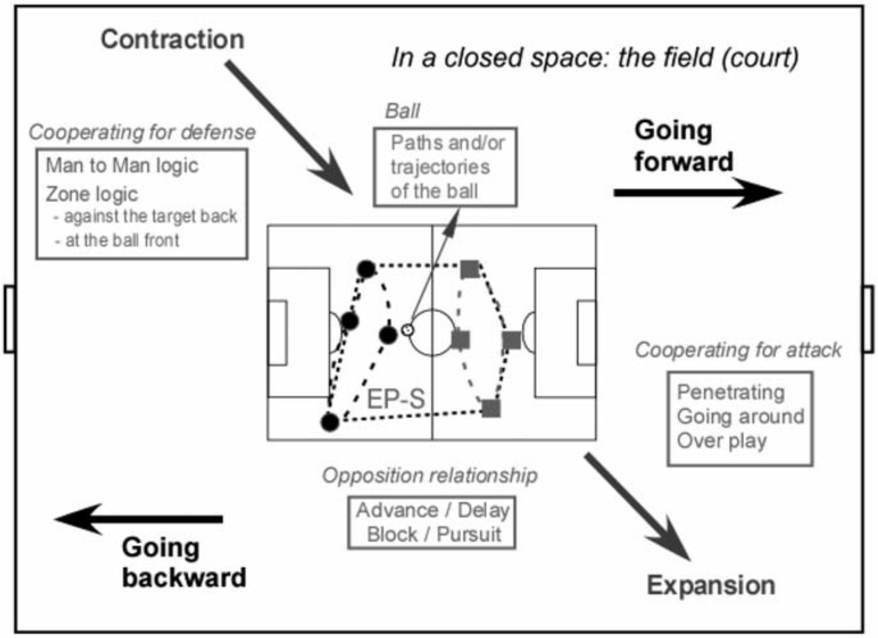

Figure 16. A dynamic system model for invasive team sports. The defense is in block (black circles).

Conclusion

The task of a team sport player lies in detecting, during game-play, incipient evolutions in the opposition relationship. The player must infer or deduct the choices of appropriate successive actions, for both offensive and defensive purposes, given possible game situations that can develop on the playing surface at any moment. The relative positioning of defenders to one another, their location on the field and their proximity or not to the target area (e.g. basket) have been shown to be important environmental constraints in the behaviors of attackers in team sports. Task constraints are specific to the task at hand (given configuration of play) and are related to the purpose of the game and to the action rules that govern the sequence of play (cf. Glazier, 2010). Scoring goals (or points) or defending a lead are key task constraints in sport. In this case, instructions, strategy and tactics help players and must be considered as major in the management of game-play.

The shape of a particular-game play configuration, like the orientation of offensive or defensive action, makes sense according to the characteristics of evolving actions from the opposing team. Understanding these reciprocal relationships between the state of movement of the two dimensions of opposition (offense vs. defense), and knowing how they operate in real game-play, constitutes, by definition, tactical intelligence with regards to opposition.

So, it is almost impossible to re-create all such situations during practice sessions, but if one considers their characteristics, they can be categorized into a smaller number of patterns in a coherent model. Essential to the learning process is the need for players to be provided with opportunities to learn and to perceive key specifying information sources within a constrained environment (Gréhaigne, Godbout y Bouthier, 2001). As a result, players should be able to produce functional behaviors or answers to momentary configurations of play whatever their complexity.

Finally, dynamic modeling of game-play in soccer can bring about a better understanding of best playing practices. This kind of modeling and the observational tools also provide knowledge and coaches can gain deeper insight from players' training. This allows a coach to try out new strategies and to obtain feedback on how these strategies work in the team.

COMO EVOLUCIONA EL "RAPPORT DE FORCES" DURANTE UN PARTIDO DE FUTBOL: LA DINAMICA DE LA TOMA DE DECISIONES COLECTIVA EN UN SISTEMA COMPLEJO

PALABRAS CLAVE: Fútbol, Sistemas complejos, Modelos, Táctica

RESUMEN: Este artículo pretende contribuir al estudio de la dinámica de sistemas complejos, en relación con el análisis del rendimiento en el fútbol. Se presentan herramientas de evaluación para comprender mejor cómo la "relación de fuerzas" evoluciona en función de las diferentes variaciones del juego, la contracción/ampliación de las fases del juego, y la posesión de balón. La aplicación de estas herramientas y modelos permitirá a los investigadores y entrenadores analizar más eficientemente la estructura del juego y poder identificar posibles obstáculos para el éxito. En general, no se puede entender la dinámica de los deportes de equipo, si no es desde una perspectiva espacio-temporal. Esto permite vislumbrar tendencias cambiantes del sistema. De esta manera, será posible entender cuáles son las conductas funcionales de los jugadores y sus respuestas a las configuraciones específicas del juego, sea cual sea la complejidad de éste.

COMO E QUE O "RAPPORT DE FORCES" EVOLUI NUM JOGO DE FUTEBOL: A DINAMICA DAS DECISOES COLECTIVAS NUM SISTEMA COMPLEXO

PALAVRAS-CHAVE: Futebol, Sistemas complexos, Modelos, Tática

RESUMO: Este artigo discute a contribuição da dinâmica para o estudo de sistemas complexos, no que respeita à análise da performance em futebol. São apresentados instrumentos de avaliação para melhor compreender como é que o "rapport de forces" (jogo de forças) evolui com as perturbações nas jogadas, as contrações/expansões das fases do jogo, e a posse da bola. É hipotetizado que a aplicação destes instrumentos e modelos permite aos investigadores e aos treinadores analisarem eficientemente configurações do jogo e identificar aquelas que parecem ser críticas para o sucesso. No geral, nada pode ser fundamentalmente compreendido sobre os desportos de equipa se não se mudar de um sistema de referência espacial para um temporal. Este torna possível iluminar as tendências evolutivas do sistema. Desta forma, é possível compreender como os jogadores produzem comportamentos funcionais ou respostas a configurações momentâneas do jogo, qualquer que seja a sua complexidade.

References

Araújo, D., Davids, K., Bennett, S. J., Button, C. and Chapman, G. (2004). Emergence of sport skills under constraints. In A. M. Williams y N. J. Hodges (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 409-433). London: Routledge, Taylor & Francis.

Bouthier, D. (1988). *Les conditions cognitives de la formation d'actions sportives collectives*. Unpublished doctoral dissertation. Université Paris V. EPHE.

Caty, D., Meunier, J. N. and Gréhaigne, J. F. (2007). Modélisations des attaques réussies pour progresser dans les sports collectifs en EPS. *Spirales, 40*, 105-116.

Chow, J., Davids, K., Button, C., Shuttleworth, R., Renshaw, I. and Araujo, D. (2007). The role of nonlinear pedagogy in physical education. *Review of Educational Research*, *77*, 251 278.

Davis, W. and Broadhead, G. (2007). *Ecological task analysis and movement*. Champaign, IL: Human Kinetics.

Davids, K., Button, C. and Bennett, S. J. (2008). *Dynamics of Skill Acquisition: a constraint led approach*. Champaign, IL: Human Kinetics.

Davids, K., Araújo, D. and Shuttleworth, R. (2005). Applications of dynamical systems theory to football. In T. Reilly, J. Cabri y D. Araújo (Eds.), *Science and football V*, (pp.537-550). London: Routledge, Taylor & Francis.

Deleplace, R. (1979). *Rugby de mouvement - Rugby total*. Paris: Éducation Physique et Sport.

Garganta, J. (1997). *Modelação táctica do jogo de Futebol - Estudo da organização da fase ofensiva em equipas de alto rendimento*. Unpublished doctoral dissertation. FCDEF - UP, Portugal.

Glazier, P. (2010). Game, set and match? Substantive issues and future directions in performance analysis. *Sports Medicine*, *40*, 625-634.

Gréhaigne, J. F. (1989). *Football de mouvement. Vers une approche systémique du jeu*. Unpublished doctoral dissertation. Université de Bourgogne, Dijon, France.

Gréhaigne, J. F. (1990). Analyse des mouvements collectifs précédant un but en football. *Science et Motricité*, *12*, 41-53.

Gréhaigne, J. F. (1992). *L'organisation du jeu en football*. Paris: ACTIO.

Gréhaigne, J. F. (2001). *La organización del juego en el fútbol*. Barcelona: INDE.

Gréhaigne, J. F. (Ed.). (2009). *Autour du temps. Espaces, apprentissages, projets dans les sports collectifs*. Besançon: Presses de l'Université de Franche-Comté.

Gréhaigne, J. F. y Godbout, P. (1995). Tactical knowledge in team sports from a constructivist and cognitivist perspective. *Quest, 47*, 490-505.

Gréhaigne, J. F., Bouthier, D. and David, B. (1997). Dynamic systems analysis of the opponent relationships in the collective actions in soccer. *Journal of Sports Sciences, 15,* 137-149.

Gréhaigne, J. F., Caty, D. and Marle, P. (2004). L'apport de la notion de configuration du jeu à la didactique des sports collectifs. In G. Carlier (Ed.), *Si l'on parlait du plaisir d'enseigner l'éducation physique* (pp. 167-179). Montpellier: AFRAPS.

Gréhaigne, J. F., Caty, D. and Marle, P. (2007). Étude systématique de différentes configurations du jeu dans les jeux réduits. In J. F. Gréhaigne (Ed.), *Configurations du jeu. Débat d'idées et apprentissage du football et des sports collectifs* (pp. 30-47). Besançon: Presses de l'Université de Franche-Comté.

Gréhaigne, J. F., Godbout, P. y Bouthier, D. (1999). The foundations of tactics and strategy in team sports. *Journal of Teaching in Physical Education, 18,* 159-174.

Gréhaigne, J. F., Godbout, P. and Bouthier, D. (2001). The teaching and learning of decision making in team sports. *Quest*, *53*, 59-76.

Gréhaigne, J. F., Richard, J. F. and Griffin, L. (2005). *Teaching and learning team sports and games*. New York: Routledge Falmer.

McGarry, T., Anderson, D., Wallace, S., Hughes, M. and Franks, I. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences, 20*, 771-781.

Mérand, R. (1977). *L'éducateur face à la haute performance olympique*. Paris, France: Sport et Plein air.

Planck, M. (1941). *Initiation à la physique*. Paris: Flammarion.

Walliser, B. (1977). *Systèmes et modèles. Introduction critique à l'analyse de systèmes.* Paris: Le Seuil.